An Roinn Comhshaoil, Aeráide agus Cumarsáide
Department of the Environment, Climate and Communications

INFOMAR
Integrated Mapping for the Sustainable Development of Ireland's Marine Resource

CE20_02 INFOMAR Survey Report
Area: Celtic Sea

Marine Institute & Geological Survey Ireland

RV *Celtic Explorer*

May 2020

Prepared by Kevin Sheehan & INFOMAR Survey Team

Foras na Mara Marine Institute

Geological Survey Suirbhéireacht Gheolaíochta Ireland | Éireann

INFOMAR is funded by the Department of the Environment, Climate and Communications and jointly managed by the Geological Survey Ireland and the Marine Institute

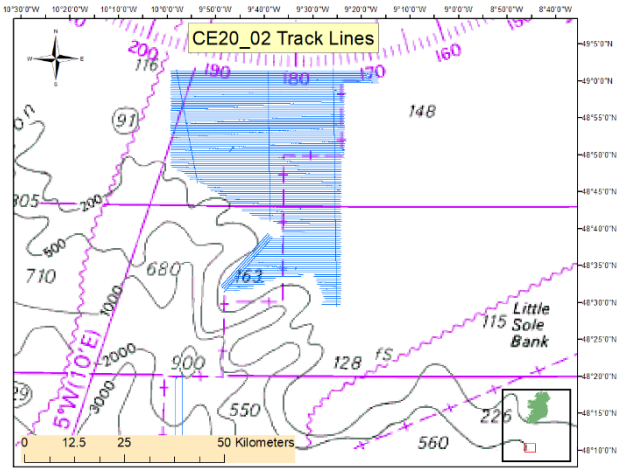
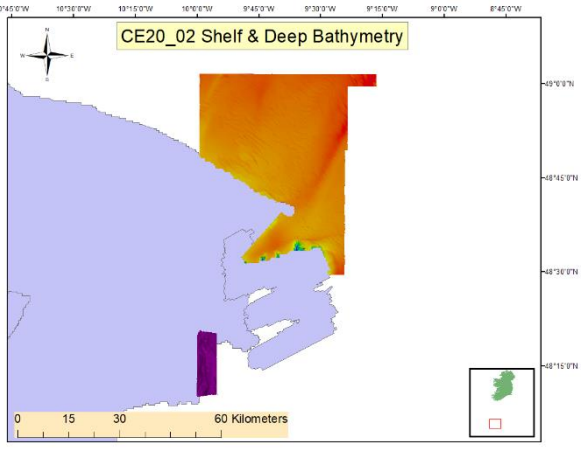
Marine Institute Reference No:	Survey Report: CE20_02

		Signature	Date
Compiled by	Kevin Sheehan	*Kevin Sheehan*	28/01/2021
Checked	Oisin McManus	*Oisin McManus*	26/02/2021
Project Managers: Marine Institute & Geological Survey Ireland			

Issue	Change	Date	Description	By	Approved
1		28/01/2021	Draft for approval	K. Sheehan	
2		26/02/2021	Final	K. Sheehan	O. McManus

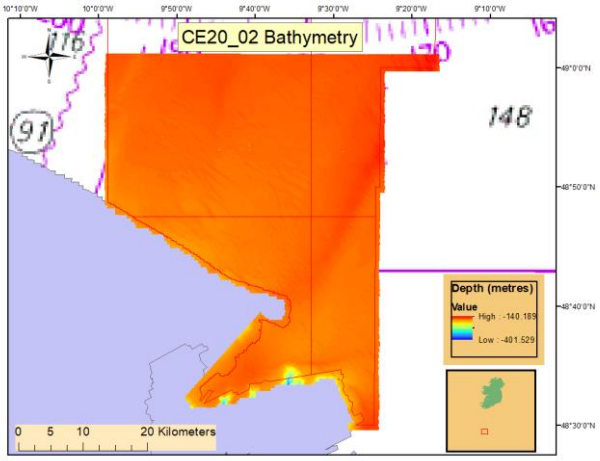
Executive Summary			
Survey Summary			
Survey Vessel:	RV *Celtic Explorer*	**Survey Leg:**	CE20_02
Mobilisation:	Galway	**Demobilisation:**	Galway
Survey Areas:	Celtic Sea	**Start Date:** **End Date:**	16/05/2020 31/05/2020
Northeast Boundary	49º 01.484N -9º 16.519W	**Southwest Boundary**	48º 09.962N -9º 58.752W
UKHO Admiralty	0002 (1:1,500,000)		
Key References	CE20_02 Survey Leg Report & CE20_02 Executive Report		
Equipment Used	EM2040 & EM302 multibeams, Echoes 3500 T7 Chirp sub-bottom profiler, EK60 singlebeam, SeaSpy magnetometer, AML MVP200, Valeport SVP Mini, C-Nav 3050 GNSS.		

Survey Statistics			
Minimum Water Depth Shelf & Deep (VORF LAT):	140 m 1264 m	**Maximum Water Depth Shelf & Deep (VORF LAT):**	402 m 3207 m
Area Covered:	1982 km^2	**Survey Line Kilometres:**	4201 km
Approximate Operational:	73%	**Approximate Downtime :**	2.7%
Groundtruthing Stations:	0	**Wrecks**	9
H525 forms issues (wrecks)	9	**H102 forms issued (shoals)**	0

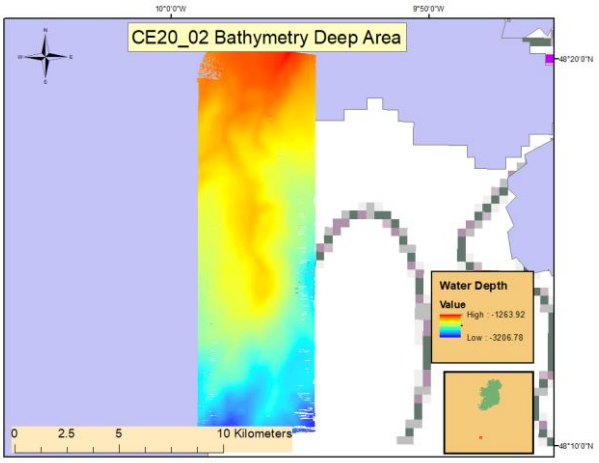
Survey Track Lines	Multibeam Bathymetry Overview
	

Survey Images

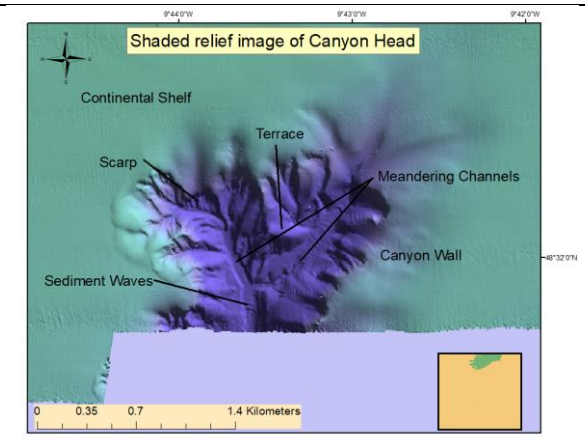
Multibeam Shelf Bathymetry



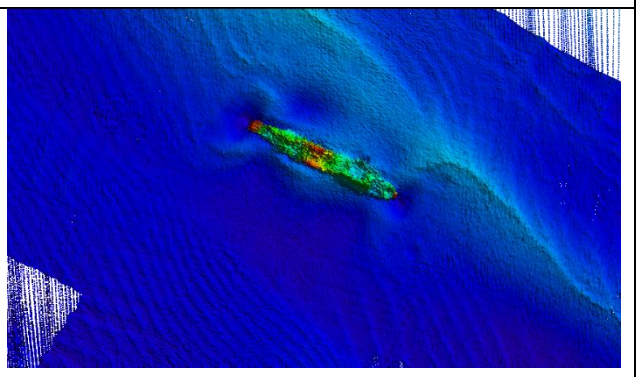
Multibeam Deep Bathymetry



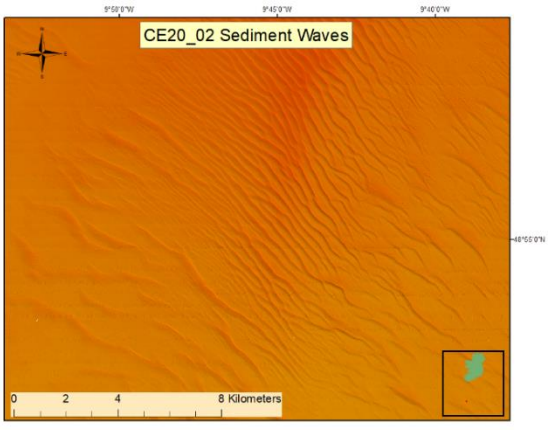
Canyon on Shelf Break



Multibeam Wreck Image



Sediment Waves



Survey Statistics

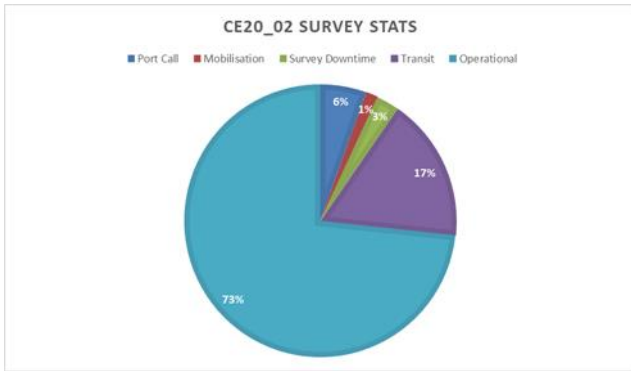


Table of Contents

Table of Figures

Table of Tables

List of Acronyms Used Within This Report

Acronym	Full Name
AML	AML Oceanographic
BIST	Built In Self Test
CTD	Conductivity Temperature Depth
CUBE	Combined Uncertainty and Bathymetry Estimator
DECC	Department of the Environment, Climate and Communications
DGNSS	Differential Global Navigation Satellite Systems
DPR	Daily Progress Report
FMGT	Fledermaus Geocoder Tool
GIS	Geographic Information System
GNSS	Global Navigation Satellite Systems
GSI	Geological Survey Ireland
HSE	Health Safety & Environment
HVF	Hips Vessel File
IHO	International Hydrographic Organisation
INFOMAR	INtegrated Mapping FOr the Sustainable Development of Irelands MArine Resource
INSS	Irish National Seabed Survey
ITRF2014	The International Terrestrial Reference Frame
LAT	Lowest Astronomical Tide
MBES	Multibeam Echo Sounder
MVP	Moving Vessel Profiler
MI	Marine Institute
MRU	Motion Reference Unit
NPWS	National Parks & Wildlife Service
PPE	Personal Protective Equipment
PPS	Pulse Per Second
PPP	Precise Point Positioning
QINSy	Quality Integrated Navigation System
RTG	Real Time Gypsy
RV	Research Vessel
SBP	Sub-Bottom Profiler
SBES	Singlebeam Echo Sounder

SIS	Seafloor Information System
SVP	Sound Velocity Profile
TPU	Total Propagated Uncertainty
UKHO	UK Hydrographic Office
UTC	Coordinated Universal Time
VORF	Vertical Offshore Reference Frame
WGS	World Geodetic System

1 Introduction

1.1 Project Overview and Objectives

The Geological Survey Ireland (GSI) and Marine Institute (MI) conducted seabed mapping between 2003 and 2005 under the auspices of the Irish National Seabed Survey (INSS) and from 2006 to present day under the INtegrated mapping FOr the sustainable development of Irelands MArine Resource (INFOMAR) programme. INFOMAR is a joint venture between the GSI and the MI. The programme succeeded the INSS which was one of the largest marine mapping programmes ever undertaken, with a focus on deep water mapping. INFOMAR is funded by the Irish Government through the Department of the Environment, Climate and Communications (DECC).

INFOMAR Phase 1, 2006 to 2015 focused on mapping 26 priority bays and 3 priority areas around Ireland and creating a range of integrated mapping products of the physical, chemical and biological features of the seabed in those areas. INFOMAR Phase 2, 2016 to 2026 intends to map the remainder of Ireland's entire seabed. Figure 1 shows the extent of the mapped area under INSS and INFOMAR and the outstanding areas as of January 2020. Grey areas have already been mapped, blue and coloured hatched areas are unmapped.

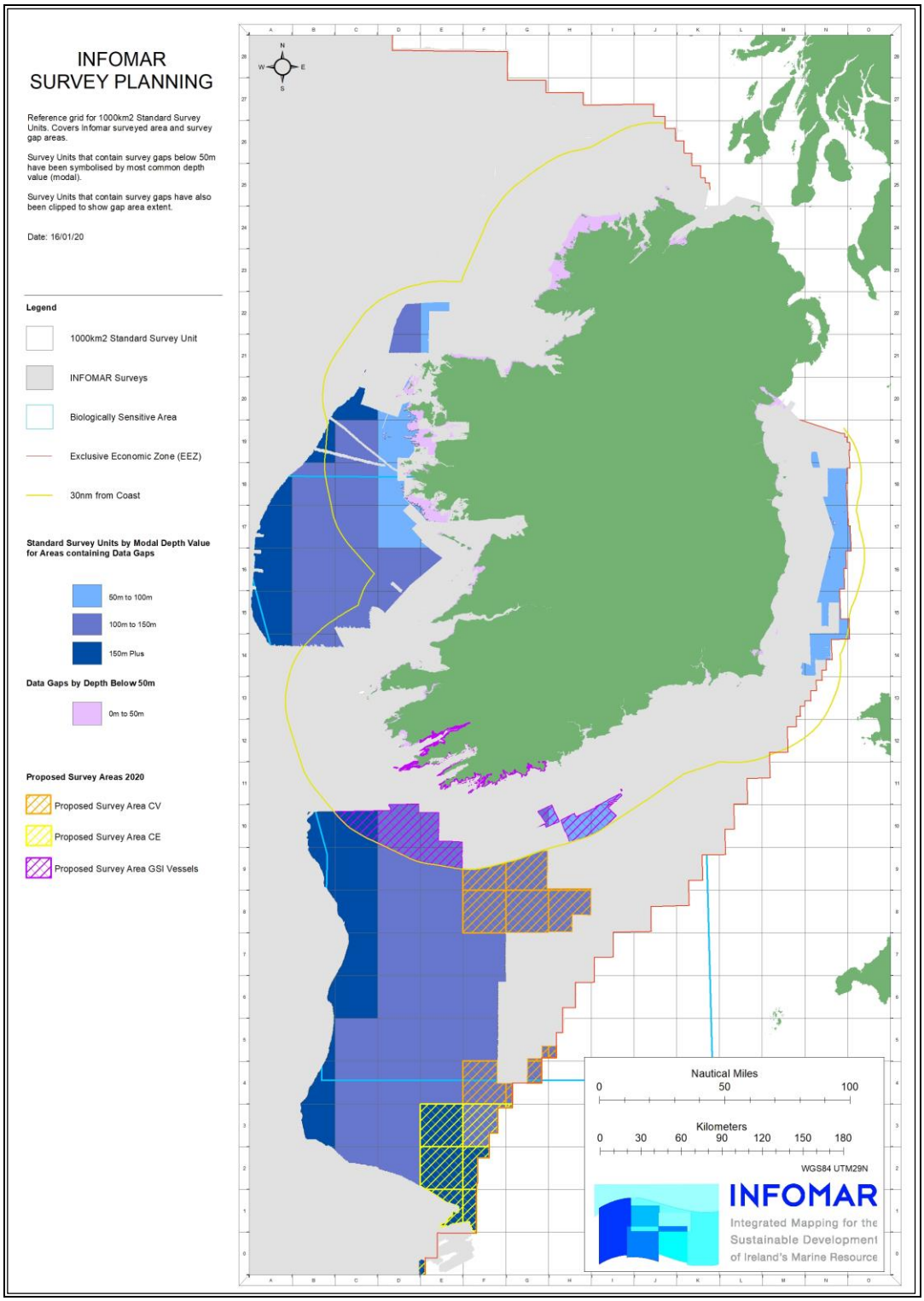


Figure 1: Survey coverage status January 2020.

MI supplied the research vessel RV *Celtic Explorer,* MI personnel and experienced contractors for the survey.

The scientific aims of the survey were to:

(i) Undertake a Multibeam Echo Sounder (MBES) hydrographic survey to a minimum standard of International Hydrographic Organisation (IHO) Order 2.

(ii) Produce bathymetry, shaded relief and backscatter mosaic products to provide depth, seabed features and seabed hardness/roughness information.

(iii) Acquire Sub Bottom Profiler (SBP) data of the shallow (up to 30 metres) sub seabed to determine the existence of buried objects and ascertain the sub-seabed character.

(iv) To map in detail and provide hydrographic wreck reports on any wrecks.

(v) To acquire MBES water column data from the EM2040 and EM302 for 3D biomass studies and imagining of other acoustic reflectors in the water column.

(vi) To acquire Moving Vessel Profiler (MVP) data for calibration of the acoustic data and investigation of the thermocline.

1.2 Survey Area

Figure 2 shows the designated survey area in yellow hatching. The RV *Celtic Explorer* designated area is located near the southern end of our unmapped area. The inset image shows the overall shelf coverage to date. Mapped areas are in grey and unmapped in white. The entire area is split into 1000 Km^2 grids, orientated north-south and east-west. The 2020 RV *Celtic Explorer* and RV *Celtic Voyager survey* areas are located in the Celtic Sea in sites selected for their strategic fisheries importance and for optimum deployment of our vessel resources.

Acquisition commenced in the proposed survey area at the southern boundary of CE20_01 (see survey report CE20_01) coverage, which finished the previous month. The entire hatched shelf area in Figure 2 along with a deep water area (Figure 2) to the south were mapped.

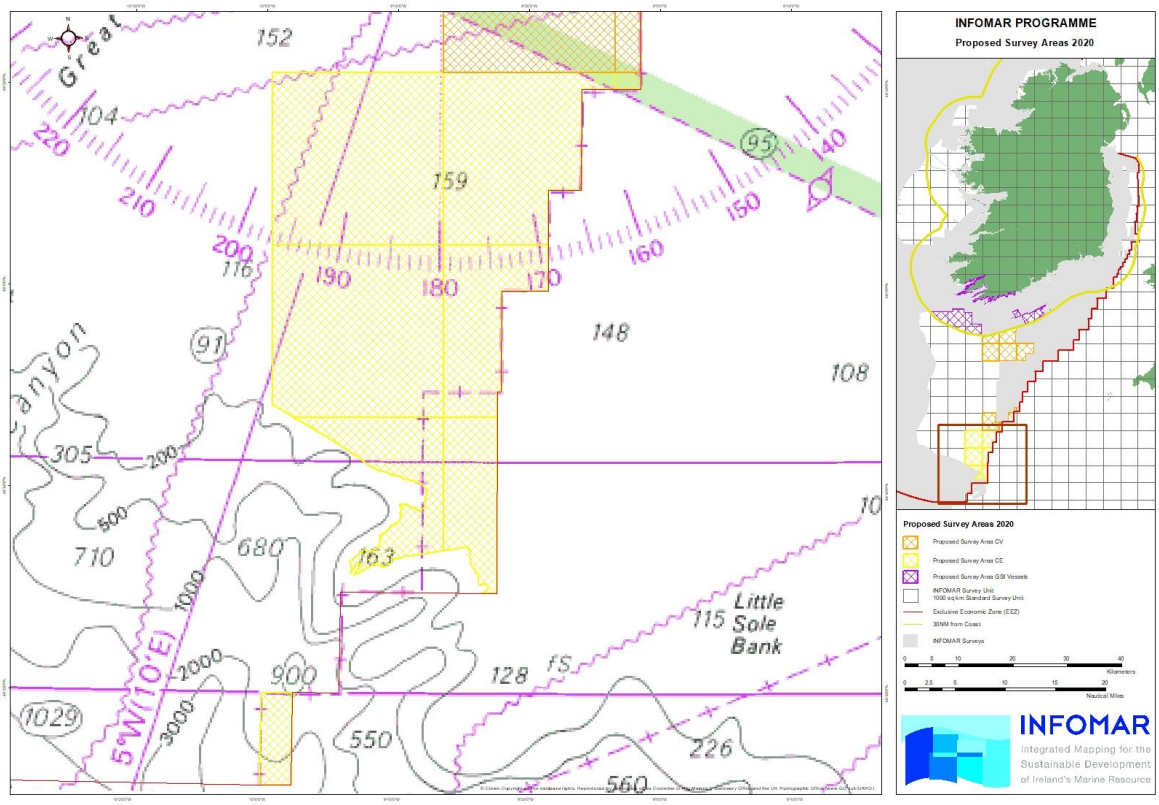


Figure 2: RV *Celtic Explorer* proposed survey areas for 2020.

2 Operations

Mobilisation took place in Galway City on 16th May. Data acquisition took place between 18th and 30th May. Kevin Sheehan of MI acted as Party Chief.

2.1 Survey Track Lines

The final survey track line plot is shown in Figure 3. Main lines were run along east – west reciprocal headings for the majority of the time with cross lines on north - south reciprocal headings.

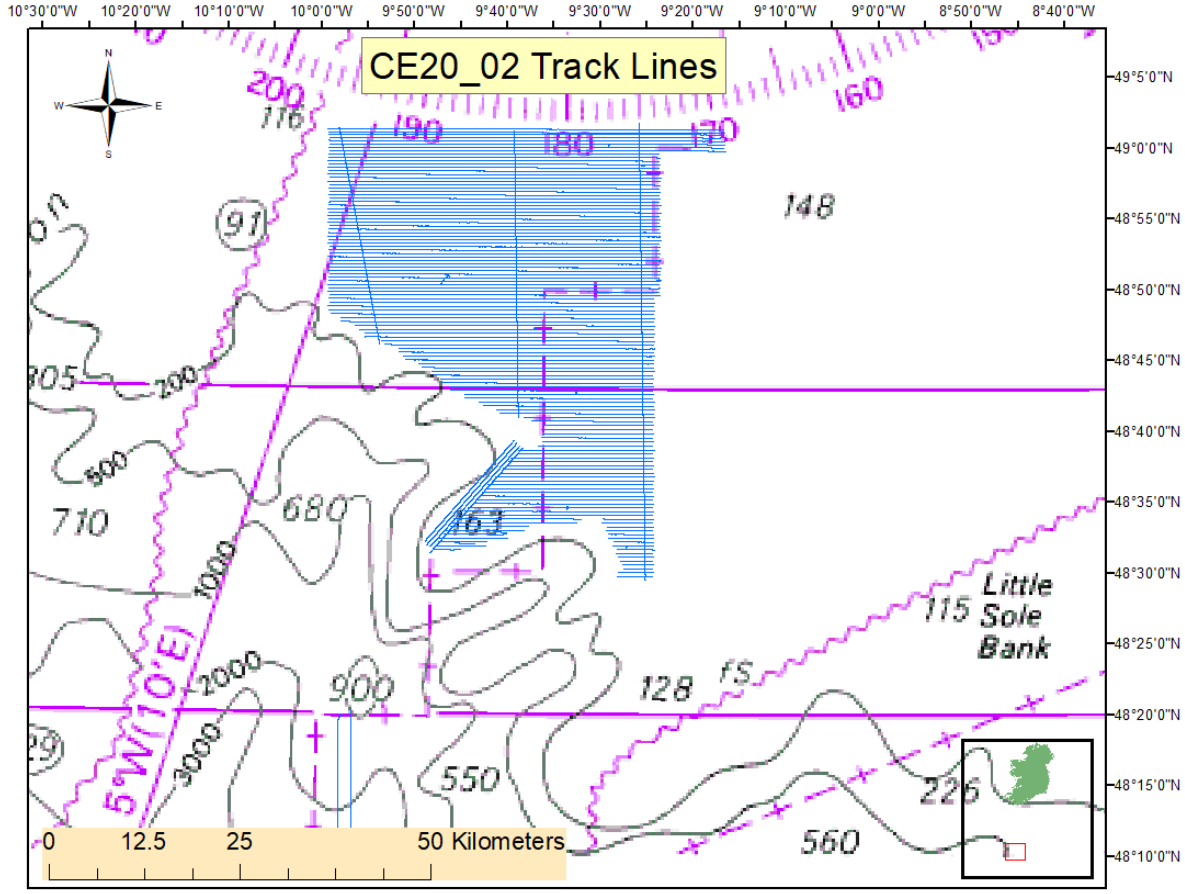


Figure 3: Survey track line plot produced in ArcGIS software.

2.2 Summary of Events

A summary of the key events is presented in Table 1. Times are in Coordinated Universal Time (UTC). Daily Progress Reports (DPRs) were emailed to management and INFOMAR personnel on a daily basis.

Date and time	Activity	Comments
16/05/20 00:00	Port Call	Galway
16/05/20 08:00	Mobilisation	
16/05/20 13:30	Downtime Survey. EM2040 Tx Faulty	Replacement Tx and wait for next tide
17/05/20 00:00	Departed Galway	Transited to Celtic Sea site
18/05/20 07:00	Commenced Survey Acquisition	MVP not deployed
19/05/20 12:00	MVP Repaired and Deployed	
21/05/20 16:00	Recovered Towed Sensors	Bad weather
23/05/20 08:00	Deployed Towed Sensors	
24/05/20 11:00	EM2040 Patch Test	No changes required
27/05/20 09:30	Transit to Deep Water Site	
27/05/20 11:00	Commenced Survey Acquisition	EM302 only
27/05/20 13:30	Transited to Shelf Site	
27/05/20 15:00	Commenced Survey Acquisition	
30/05/20 03:30	Finished Acquisition	Commenced Transit to Galway
31/05/20 11:00	Alongside Galway	
31/05/20 23:59	Demobilisation completed	

Table 1: Summary of survey events.

2.3 Survey Personnel

Survey personnel are listed in Table 2.

Name	Affiliation	Role
Kevin Sheehan	MI	Party Chief
Nicola O' Brien	MI	Surveyor
Agust Magnusson	Contractor	Data Processor
Jan Majcher	Contractor	Surveyor

Table 2: Survey personnel details.

2.4 Health, Safety and Environment (HSE)

All personnel joining the vessel were given a safety induction tour which was recorded by the Second Mate. Medical and Personal Sea Survival certifications for all personnel were checked for validity prior to departure. A muster drill was held within 24 hours of departure from port. Magnetometer and sound velocity profiler deployments were performed by vessel crew and without incident, with personnel wearing correct Personal Protective Equipment (PPE). There were no near misses or safety incidents to report.

2.5 Marine Mammal Observations

National Parks and Wildlife Service (NPWS) published a *Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters* in 2007. An updated document titled "Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters" was published in January 2014. Full details of both documents are published on the NPWS website. The code and guidance are applicable to all seismic, MBES and sidescan sonar surveys in bays, inlets or estuaries and within 1500 m of the entrance of enclosed bays/inlets/estuaries. All CE20_02 operations were outside of the areas covered under the above guidelines.

2.6 General Survey Information

A summary of principal survey statistics is contained in Figure 4. The vessel was operational 73% of the time and no weather standby was experienced. Survey downtime was 3% and much of this was due to a technical fault that resulted in a missed tide at Galway. Survey operations were at reduced speed at times due to strong winds and rough seas but this is not accounted for in the statistics. A total of 4201 line km and 1983 km^2 were mapped.

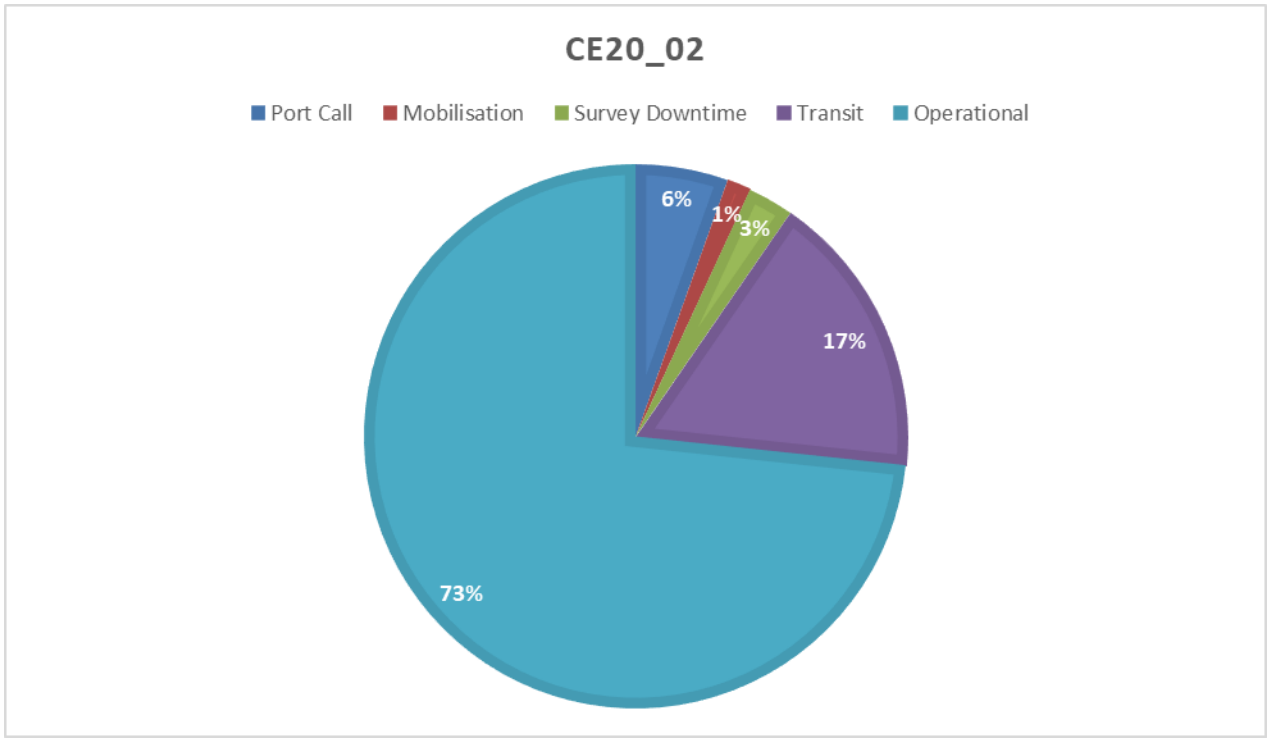


Figure 4: Survey statistics pie chart CE20_02.

2.7 Wreck and Shoal Investigations

United Kingdom Hydrographic Office (UKHO) guidelines were implemented for wreck investigations. Three survey lines along the wreck's primary axis with high overlap and one

line across its secondary axis (ensuring full wreck coverage along both axes) were acquired. The water column logging functionality in SIS was used throughout the investigation. Beam angles, survey speed, operational frequency and pulse length were configured for maximum resolution.

Uncharted shoals are surveyed in a similar manner where conditions allow. Wrecks and shoals are reported to the UKHO using the standard UKHO “H-Forms”. No shoals were discovered or mapped. Nine wrecks were mapped in detail and wreck reports produced and distributed to the Underwater Archaeology Unit at the Department of Housing, Local Government and Heritage and UKHO. Table 3 contains wreck metadata information.

Descriptor	**Metadata**
Shoals	0
Wrecks	9

Table 3: Hydrographic reports completed.

3 Survey Vessel Offsets, Equipment and Data Acquisition

The RV *Celtic Explorer* (Figure 5) is a multipurpose research vessel owned by MI and managed by P&O Maritime. The vessel has wet, dry and chemical laboratories, which are permanently fitted with standard scientific equipment and can accommodate 35 people with a maximum endurance of 45 days. It has two high resolution MBES systems, a Singlebeam Echo Sounder (SBES), fisheries echo sounder, chirp source SBP and C-NAV Differential Global Navigation Satellite Systems (DGNSS). All necessary geophysical and DGPS positioning equipment were pre-installed, calibrated and tested prior to commencement of survey activities.

Figure 5: The RV *Celtic Explorer*.

Detailed vessel information is contained in Table 4.

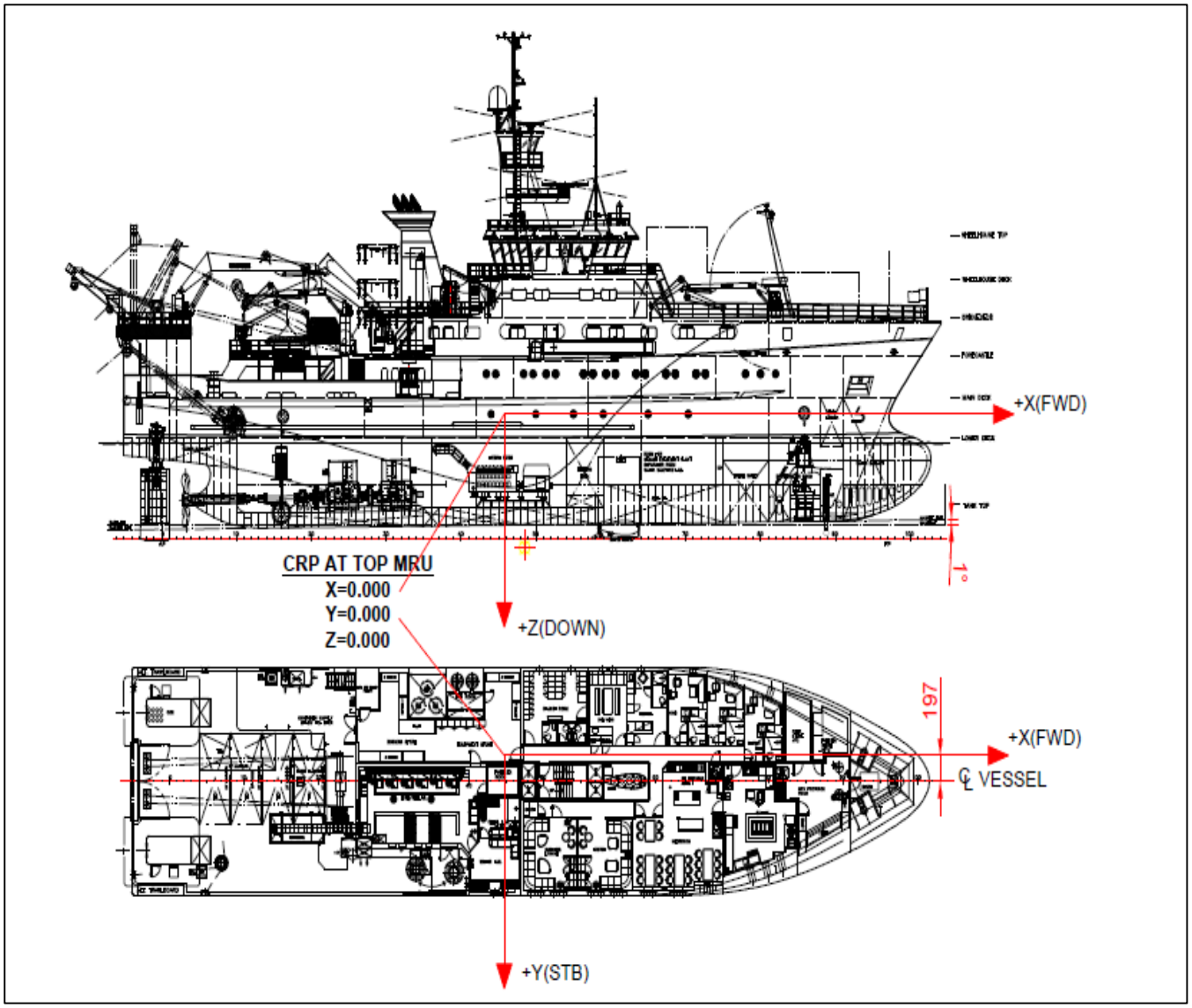
Length	65.5 m
Beam	15 m
Draught	6.0 m
Engine	1 x 6L20, 2 x 9L20
Power Output	1 x 1080 kWa, 2 x 1680 kWa
Speed	10 knots
Fuel	4600 Lt per day MGO
Generator	1 x 1080 kWa, 2 x 1680 kWa

Max Scientists and Crew	35
Passenger Licence	P5

Table 4: RV *Celtic Explorer* vessel information.

3.1 Vessel Offsets

Bluepix AS performed a vessel offset survey between 10th and 15th January 2015 while the vessel was in dry dock in Falmouth, UK. An EM302 deep water MBES and an IxBlue ECHOES3500 Chirp system were installed on the vessels hull during this dry dock. Vessel offsets are presented in Table 5 below. The EM1002 is obsolete as of 2020.



Item	Y (+Stb)	X (+Fwd)	Z (+Down)	Description
MRU5+	0,000	0,000	0,000	Position Centre Top
EM302 TX	0,199	20,022	7,056	Position Centre Face
EM302 RX	0,202	17,574	7,106	Position Centre Face
EM 2040 TX	0,416	11,204	7,205	Position Centre Face
EM 2040 RX	0,111	11,098	7,192	Position Centre Face
EM 1002	0,195	13,846	7,964	Position Centre U/S
Seapath aft	0,235	1,506	-25,006	Geometric Centre
Seapath Fore	0,205	3,980	-24,966	Geometric Centre
C-Nav	-0,211	2,838	-24,925	Geometric Centre U/S Antenna
IXSEA ECHOS SBP	0,194	16,317	7,130	Centre Face
ES 120	-0,073	12,289	7,161	Centre Face
ES 38	0,199	12,581	7,160	Centre Face
ES 200	0,474	12,290	7,167	Centre Face
ES 18	0,203	11,901	7,171	Centre Face
USBL 1 and 2	0,212	9,988	7,239	Flush U/S Drop keel
Draftsensor Fore Stb	3,484	23,316	4,181	Centre Flush Hull
Draftsensor Fore Port	-3,067	23,314	4,185	Centre Flush Hull
Draftsensor Port Midship	-7,053	-5,133	4,436	Centre Flush Hull
Draftsensor Stb Midship	7,608	-4,067	4,400	Centre Flush Hull
Draftsensor Aft Stb	2,064	-14,217	6,240	Centre Flush Hull
Stb Point for draft measurement	7,719	-4,582	-2,179	Railing Stb side
Stb Point for draft measurement	7,147	11,245	-4,985	Welded mark
Port Point for draft measurement	-7,474	-1,969	-4,945	Railing Port side

Item	Pitch	Roll	Yaw
MRU 5+	0.73	-1.11	-0.36
EM2040 TX	1.25	-0.38	-0.23
EM2040 RX	0.55	0.16	-0.12
EM302 TX	1.03	0.42	-0.05
EM302 RX	1.68	0.06	0.04
Seapath	N/A	N/A	-0.70
EM1002	0.86	0.01	-0.65

Positive Yaw is clockwise. Positive Roll is starboard down. Positive Pitch is fore up.

Table 5: Vessel offsets and installation angles.

3.2 Survey Equipment

Table 6 contains information on the survey equipment both permanently installed and available for mobilisation on board the RV *Celtic Explorer*.

Data System	Make/Model	Comment
Multibeam Echo-Sounder	Kongsberg EM2040	200, 300 & 400 kHz
Multibeam Echo-Sounder	Kongsberg EM302	26.5 to 33.5 kHz
Singlebeam Echo-Sounder	Kongsberg EA600	12, 38 & 200 kHz

Fisheries Echo-Sounder	Kongsberg EK60	18, 38, 120 & 200 kHz
Chirp Sub-Bottom-Profiler	iXblue Echoes 3500 T7	3.5 – 9 kHz
Sidescan Sonar	Edgetech 4200	100 and 500 kHz
Positioning	C-Nav DGNSS	Seapath330+ as secondary
USBL	iXSEA-Gaps	Sonardyne Scout as secondary
Sound Velocity Profilers	Valeport SVX2 & SVP Mini	SV & Conductivity
Moving Velocity Profilers	AML MVP-200	CTD & SVP sensor
Realtime Sound Velocity	Valeport & AML	
Magnetometers	SEASPY	Overhauser Effect
Acoustic Doppler Current Profiler	Teledyne	76.8 kHz

Table 6: RV *Celtic Explorer* available survey equipment.

3.2.1 Technical Issues

EM2040 Tx Failure

A failed Built In Self Test (BIST) in SIS during mobilisation necessitated troubleshooting. Reboot of the PC and Processing Unit failed to solve the issue. New cables were connected between the transducer situated on the dropkeel and the Processing Unit but this also failed to solve the issue. A spare Tx transducer was sent on-board to replace the existing Tx and the BIST was re-run. The BIST passed and the system was deemed fit for use. The fact that the Tx on the Celtic Explorer is located on the dropkeel allowed the Tx to be changed without the need for divers or a dry docking and this saved valuable time.

Qinsy Navigation PC Failure

The Qinsy PC hard drive failed during mobilisation testing and a replacement PC was configured for the survey.

MVP Communication Failure

The MVP was tested during transit and a communications failure was found. The towfish was recovered. The technician tested the tow cable and discovered serval shorts. Cable was cut and reterminated.

MVP Winch Failure

We were unable to communicate with the MVP winch. AML assisted with troubleshooting and we were eventually able to establish communications. The internal winch computer was found to have reset itself to a default position where it was unable to do anything. This setting was changed and the winch was made fully functional.

Magnetometer Failure

Anomalous readings were recorded mid-survey. Different components were swapped out to isolate the fault and it was determined that the fault was with the tow cable. The spare tow cable was configured and the system worked well.

3.3 Data Acquisition

3.3.1 Geodetic Parameters

Table 7 contains the geodetic parameters used for the survey.

Local Datum Geodetic Parameters	
Datum	ITRF2014
Spheroid	World Geodetic System 1984 (WGS-84)
Semi-Major Axis (a)	6378137.000 m
Semi-Minor Axis (b)	6356752.314 m
First Eccentricity Squared (e^2)	0.0066943800
Inverse Flattening (1/f)	298.257223563
Projection Parameters	
Grid Projection	Universal Transverse Mercator
Central Meridian Zone 29 (CM)	009º West
Origin Latitude (False Lat.)	00.0°
Hemisphere	North
False Easting (FE)	500000.0 m
False Northing (FN)	0.0 m
Scale Factor on CM	0.999600
Units	Metres

Table 7: Geodetic parameters.

3.3.2 Survey Datum, GNSS Tides and VORF Model

Table 7, above details the vertical and horizontal datum applied during operations. Global Navigation Satellite Systems (GNSS) tides do not require accounting for vessel draft or vessel squat values, as recorded depths are related directly to the WGS84 Ellipsoid. These values were reduced to Lowest Astronomical Tide (LAT) using GNSS tidal measurements and by then applying the VORF (Vertical Offshore Reference Frame) model (LAT/WGS84 separation) as illustrated in Figure 6 below.

A validation of the LAT vertical datum output from the VORF model was undertaken between 2013 and 2016, using tide gauges and harmonic analysis, at key locations around the Irish

coast.

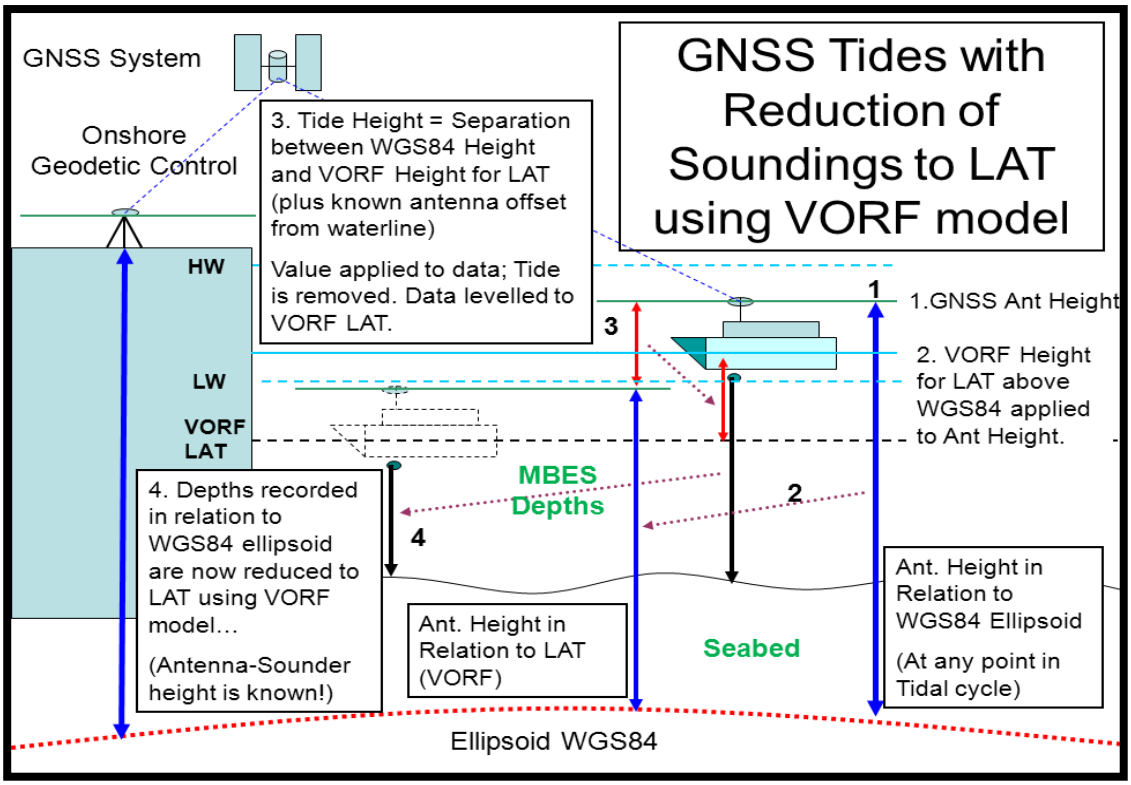


Figure 6: GNSS tides to LAT using VORF model.

3.3.3 Vessel Draft

Distances from known draft measuring points on the vessels port and starboard sides to the water line were measured by tape once ballasting was completed. Known vertical distances at port and starboard sides between these draft measuring points and the MRU (Common Reference Point for EM2040) were used along with the tape measured vertical distances to calculate draft values for the echosounders. Port and starboard sides were averaged to get one value for each echosounder. Table 8 lists the tape measured draft figures along with the known vertical distances.

Measurement	**Port Side**	**Starboard Side**
Tape Measurement at Draft Mark (from mark to water) 21/09/2019	-6.92 (E)	-4.20 (D)
Vertical distance between Starboard Side draft mark and MRU		-2.179 (A)
Vertical distance between Port Side draft mark and MRU	-4.945 (B)	

Table 8: Draft measured and known vales.

Draft value for EM2040 = ((D - A) + (E - B))/2

Draft value for EM2040 = ((-3.95 - -2.179) + (-6.85 - -4.945))/2 = **-1.998**

This draft value was entered in the respective software for all echosounders.

The EM2040 transducers are situated on the vessel drop keel. The drop keel can be placed in a range of positions including flush with the hull or fully deployed. The vertical measurement by tape is 7.75 m when the drop keel is in the flush position. The vertical measurement by tape for this survey when the drop keel was in the fully deployed position was 10.40 m. Difference between flush position and fully deployed position is 10.40 – 7.75 = 2.65 m. This figure was entered in SIS as an additional z offset. The vertical measurement when in the fully deployed position may be subject to minor variation so should be measured for each deployment.

3.3.4 Multibeam Systems

The RV *Celtic Explorer* is equipped with two MBES systems; an EM2040 and EM302, capable of high precision seabed mapping from shallow water to full ocean depths. The EM2040 is designed for high resolution mapping down to approximately 400 metres water depth. A hull mounted EM302 provides additional multispectral data and is designed to perform seabed mapping with high resolution and accuracy to a maximum depth of more than 7000 metres.

The EM2040 positioned on the drop keel is the primary system for high resolution seafloor mapping on the continental shelf. First bottom returns from the MBES produce highly accurate bathymetric data. Backscatter acquired by MBES sonars contains important information about the seafloor and its physical properties. This information provides valuable data to aid in seafloor classification and important auxiliary information for a bathymetric survey. The EM2040 can also acquire water column data for oceanographic investigations and for detection of objects above the seafloor.

The EM2040 installation consists of single RX transducer and a single TX transducer, 0.7º x 0.7º. The system operates at frequencies of 200, 300 or 400 kHz with 400 soundings per ping and allows coverage of up to 5 times water depth on a flat bottom. It has a maximum ping rate of 50 Hz. The 200 kHz frequency was used for general mapping and 300 kHz for wreck investigations. Positioning was provided by C-Nav 3050 DGNSS and these data were integrated with inertial measurement units by a Seatex Motion Reference Unit (MRU) model

Seapath 330+ to give real time heading, heave, pitch and roll, position and velocity of the MBES system.

The EM302 transducers are modular linear arrays in a Mills cross configuration with separate units for transmit and receive. The transmitter array is 1º resolution and the receive array 2º resolution. It has dual swath capability meaning that 2 swaths are generated per ping cycle, with up to 864 soundings. The system has an operating frequency of 30 kHz. It can also acquire water-column data.

MBES data was recorded in .all and .wcd formats using Kongsberg's SIS software. Raw .all files from the MBES's were continuously backed up on the vessel server. EM2040 and EM302 water column data were acquired throughout and written straight to portable disk drive as file sizes are very large. Table 9 contains MBES metadata.

Descriptor	Metadata
Survey lines	All
Date Created	18-05-2020 to 29-05-2020
EM2040 Data Files (mainlines)	200
EM302 Data Files	151
EM2040 Dataset Size	33.4 GB
EM2040 Watercolumn Size	Stored on separate disk
EM302 Dataset Size	34.4 GB
EM302 Watercolumn Size	Stored on separate disk
EM2040 File Formats	.all, .wcd
EM302 File Formats	.all, .wcd

Table 9: MBES metadata.

3.3.5 Singlebeam Systems

An EK60 fisheries echosounder mounted on the drop keel provided data for investigation of the thermocline. The EK60 is a multiple frequency system with 18, 38, 120 and 200 kHz capability. The 200 kHz frequency was switched off throughout as it interfered with the EM2040.

EK60 data was recorded in .raw format using Kongsberg's acquisition software. Data was backed up to the vessel server at the end of each line. Table 10 contains EK60 metadata.

Descriptor	Metadata
Survey lines	
Data Files	1513
Date Created	18-05-2020 to 30-05-2020
Dataset Size	14.8 GB

File Formats	.bot, .idx, .raw

Table 10: SBES metadata.

3.3.6 Echoes Chirp Sub-Bottom Profiler

The vessel is equipped with a hull-mounted SBP situated just aft of the EM302. Echoes 3500 T7 is a low frequency chirp SBP, based on seven transducers. The transmitted pulse is frequency and amplitude-modulated. The frequency modulation ranges from 1.7 kHz to 5.5 kHz, centred on 3.5 kHz, with a 100ms Chirp. The selected bandwidth allows for good penetration and high resolution. Acquisition is controlled in Delph acquisition software.

Raw data was recorded in XTF format for each survey line. Positioning data was provided from C-Nav DGNSS and MRU data was fed directly from the Seapath 330+. The realtime attitude data can be viewed in the Delph acquisition software but it is not applied to the seismic data in realtime. One set of acquisition parameters, based on 100 m water depth was utilised throughout the survey. Table 11 contains SBP metadata.

Descriptor	**Metadata**
Survey lines	All
Data Files	764
Date Created	18-05-2020 to 29-05-2020
Dataset Size	106 GB
File Formats	.XTF, .GEO, .PRM & .idx

Table 11: SBP metadata.

3.3.7 Magnetometer

A Marine Magnetics Corporation SeaSPY towed Overhauser Magnetometer was used to acquire magnetic field data. The system comprises a towfish, tow cable, deck lead and transceiver interfaced to a standard Windows based PC. Acquisition parameters and QC were controlled via BOB software.

The magnetometer was towed 200 m behind the vessel at a depth of less than 5 m beneath sea surface. Magnetometer and GPS data from the towfish were input to the control PC via separate serial ports and synchronised. Initial QC was performed via real-time graphing of the magnetic field trace and by monitoring real-time GPS data. Magnetometer data were recorded in a database using BOB software and output in proprietary BOB format as .mms file format. Metadata is contained in table 12. A fault with the systems halted magnetometer acquisition on 25th of May.

Descriptor	**Metadata**

Survey lines	NA
Data Files	1
Date Created	18-05-2020 to 25-05-2020
Dataset Size	499 MB
File Formats	.mms

Table 12: Magnetometer metadata.

3.3.8 DGPS Systems

C-Nav DGNSS provided the primary navigation. The C-Nav 3050 is a dynamic DGNSS Precise Point Positioning (PPP) system providing accuracy of <0.1 metre horizontally and 0.2 metre vertically. It provides 66 channel tracking, including multi-constellation support for GPS, GLONASS and Galileo. C-Nav provided the primary navigation feed for all survey equipment. C-Nav also provided a reliable GPS tide correction.

The C-Nav DGNSS receiver was connected to the server VDU for QC purposes. C-Nav has a range of QC output displays that were monitored in real-time including number of satellites in use, satellite attitude and angles, vertical accuracy, vessel speed, heading and precise position. GPS signal was always very good and the system never lost the Real Time Gypsy (RTG) solution. Raw C-Nav data were not recorded to disk during this survey but the data is embedded in the MBES and SBP files.

Seapath 330+ provided the secondary navigation. Seapath and C-Nav data were continuously checked in Quality Integrated Navigation System (QINSy) software to ensure data integrity and comparison between the primary and secondary navigation systems remained within tolerance.

3.3.9 Online Navigation

QINSy software was used for navigation acquisition and QC. QINSy performs visual and QA data-feeds from the key acquisition systems. A project template database was created containing all survey configuration parameters relevant to the project. The project template contains the datum, projections, vessel shape, administrative information, as well as vessel offsets and I/O parameters. QINSy uses a sophisticated timing routine based on the Pulse Per Second (PPS) option from the GNSS receiver. All incoming and outgoing data is accurately stamped with a UTC time label.

Survey line and MVP positioning data were recorded in QINSy software in .db and .txt format. QINSy metadata is provided in Table 13.

Descriptor	Metadata
Survey lines	All
Data Files	585
Date Created	18-05-2020 to 29-05-2020
Dataset Size	16.5 GB
File Formats	.db & .txt

Table 13: QINSy Navigation metadata.

3.3.10 Sound Velocity Profilers & Sensors

An AML Oceanographic Moving Vessel Profiler (MVP) 200 (Figure 7) was the primary instrument to obtain sound velocity profile data for the echosounders. This allowed the vessel to acquire sound velocity profiles on the fly.

Figure 7: AML Oceanographic MVP-200.

The MVP-200 was fitted with a Smart SVP sensor capable of directly acquiring sound velocity data. MVP deployment was controlled from the vessel Dry Lab using Rolls Royce MVP software. The probe was continually towed in the water at 5 metres depth off the starboard aft side and deployed to within 20 metres of the seabed during casts. Sound velocity profiles were extended in SIS and fed directly into both MBES as required.

Both Valeport and AML sound velocity sensors positioned at the transducer heads provided real time sound velocity input directly to the EM2040 and EM302 respectively. MVP metadata is contained in Table 14.

Descriptor	**Metadata**
Survey lines	NA
Data Files	2353
Date Created	17-05-2020 to 30-05-2020
Dataset Size	91.1 MB
File Formats	.asvp, .calc, .eng, s10, .s52, .log, .m1, .raw

Table 14: Sound velocity metadata.

3.3.11 Multilog

Multilog was unavailable for metadata logging for the duration of the survey.

.

4 Online QC, Data Processing, Results and Interpretation

The hydrographic survey was performed to International Hydrographic Organization (IHO) survey standards. Table 15 lists the S-44, 6th edition standards for Order 1a and Order 2 surveys. All depths in this survey exceeded 100 metres and where under keel clearance is not an issue. Criteria in Table 15 represent the minimum standard for position, depth accuracy, feature search, feature detection and bathymetric coverage achieved during data acquisition and processing. Strictly speaking CE20_02 only required Order 2 specification but in reality the data easily exceeded this standard, for example, the feature detection criteria discussed in 4.1.3.

	Order 1a (S-44)	**Order 2 (S-44)**
Description of Areas	Areas where underkeel clearance is considered not to be critical but features of concern to shipping may exist.	Areas generally where a general description of the sea floor is considered adequate.
Max THU allowable (95%C)	Total Horizontal Uncertainty (THU) 5m+5% of depth	Total Horizontal Uncertainty (THU) 20 m+10% of depth
Max TVU allowable (95%C)	Total Vertical Uncertainty (TVU) a = 0.5 metre b = 0.013 $\pm\sqrt{a^2 + (bxd)^2}$	Total Vertical Uncertainty (TVU) a = 1.0 metre b = 0.023 $\pm\sqrt{a^2 + (bxd)^2}$
Feature Search	100%	Recommended but not required
Feature Detection	Cubic Features > 2m (Depths < 40m) 10% depth > 40m	Not specified
Bathymetric Coverage	≤100%	5%

Table 15: IHO S44 v 6th edition standards for hydrographic surveys.

4.1 MBES Online Quality Control

4.1.1 Acquisition Parameters

Most of the important acquisition parameters are set in the Runtime Parameters module of SIS. Figure 8 shows the Sounder Main tab in Runtime Parameters for the EM2040. Max angle and max coverage parameters were adjusted to take account of depth, sea state and seafloor character. Pulse type was set to auto throughout, which based on the angle and coverage settings, defaulted to FM pulse. The 200 kHz frequency was used throughout.

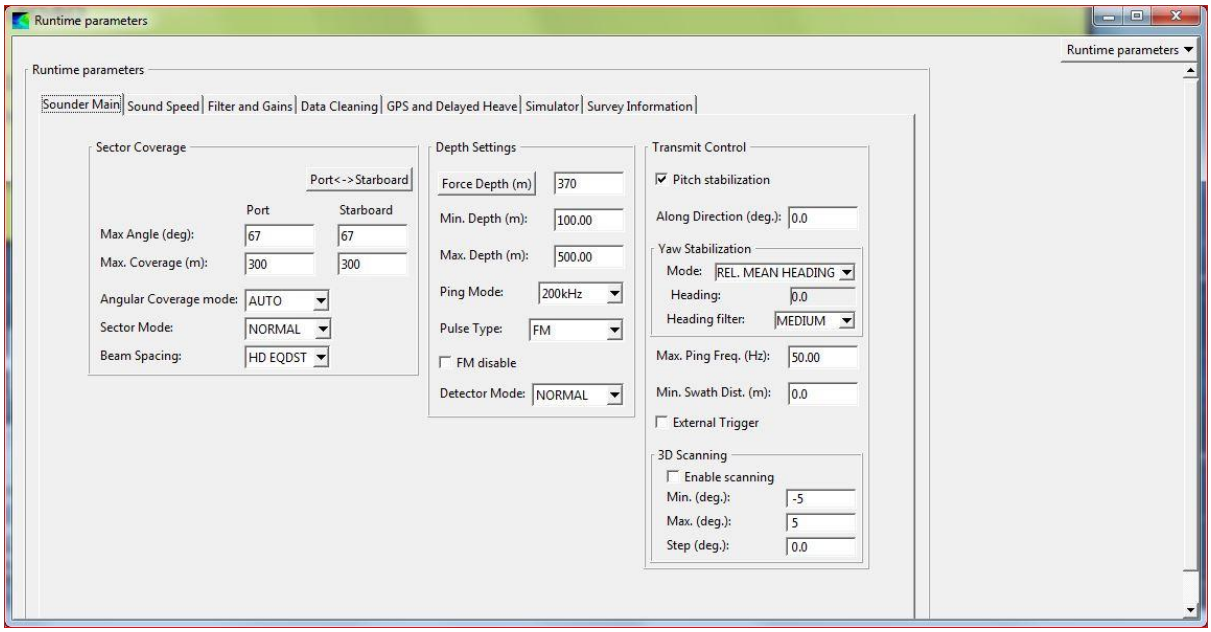


Figure 8: EM2040 runtime parameters window in SIS.

4.1.2 Crossline versus Mainline Statistics

Crossline data were acquired for QC of depth soundings. A total of five crosslines were acquired for statistical analysis in Caris Hips. EM2040 crossline data were compared with mainline data and all crossline data indicated that the soundings exceeded the 95% certainty required for Order 1a specification. Crossline statistics are presented in Table 16.

Line	Beam Number	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)	Order 1b (%)	Order 2 (%)
240	1-51	690,903	1.307	1.397	-0.085	0.208	100	100	100	100
240	51 - 101	690,666	1.021	3.523	-0.142	0.192	99.995	99.998	99.998	100
240	101 - 151	690,961	1.13	2.682	-0.161	0.19	99.991	100	100	100
240	151 - 201	690,610	1.748	1.904	-0.165	0.216	99.992	100	100	100
240	201 - 251	690,668	1.514	1.661	-0.094	0.201	99.994	100	100	100
240	251 - 301	691,010	1.383	2.058	-0.092	0.186	99.999	100	100	100
240	301 - 351	691,002	1.075	1.306	-0.086	0.187	100	100	100	100
240	351 - 400	677,145	1.266	1.439	-0.066	0.191	99.998	100	100	100

Line	Beam Number	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)	Order 1b (%)	Order 2 (%)
0241	1-51	680,583	1.934	1.183	0.065	0.24	99.981	100	100	100
0241	51 - 101	680,514	1.535	1.108	0.011	0.207	99.999	100	100	100
0241	101 - 151	681,205	1.641	1.56	0.02	0.209	99.999	100	100	100
0241	151 - 201	680,415	1.764	1.289	0.019	0.228	99.976	100	100	100
0241	201 - 251	680,651	1.624	1.298	0.093	0.22	99.982	100	100	100
0241	251 - 301	681,103	1.396	3.825	0.092	0.205	99.994	99.999	99.999	100
0241	301 - 351	681,023	1.824	1.86	0.073	0.209	99.995	100	100	100
0241	351 - 400	667,133	1.721	1.287	0.063	0.224	99.994	100	100	100

Line	Beam Number	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)	Order 1b (%)	Order 2 (%)
0242	1-51	696,457	1.452	1.358	-0.024	0.225	99.999	100	100	100
0242	51 - 101	696,469	1.49	1.349	-0.025	0.215	99.999	100	100	100
0242	101 - 151	696,480	1.282	1.395	-0.003	0.215	99.998	100	100	100
0242	151 - 201	695,591	1.572	1.387	0.021	0.239	99.987	100	100	100
0242	201 - 251	696,066	1.641	1.35	0.103	0.228	99.993	100	100	100
0242	251 - 301	696,385	1.496	1.323	0.109	0.211	99.999	100	100	100
0242	301 - 351	696,395	1.291	1.277	0.098	0.208	100	100	100	100
0242	351 - 400	682,354	1.614	2.026	0.093	0.218	99.992	100	100	100

Line	Beam Number	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)	Order 1b (%)	Order 2 (%)
0243	Jan-51	203,235	1.183	1.446	-0.132	0.192	100	100	100	100
0243	51 - 101	203,195	0.907	1.247	-0.166	0.171	100	100	100	100
0243	101 - 151	203,190	1.089	1.21	-0.169	0.175	100	100	100	100
0243	151 - 201	203,036	1.325	1.269	-0.14	0.204	100	100	100	100
0243	201 - 251	202,910	1.325	1.949	-0.074	0.188	99.987	100	100	100
0243	251 - 301	203,196	1.152	1.233	-0.047	0.166	100	100	100	100
0243	301 - 351	203,096	1.216	2.146	-0.034	0.168	99.994	100	100	100
0243	351 - 400	199,022	1.189	2.037	-0.001	0.188	99.987	100	100	100

Line	Beam Number	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)	Order 1b (%)	Order 2 (%)
0244	Jan-51	683,325	1.834	2.333	-0.298	0.272	99.743	100	100	100
0244	51 - 101	683,876	0.824	1.937	-0.273	0.26	99.74	100	100	100
0244	101 - 151	684,097	1.081	2.816	-0.23	0.255	99.853	100	100	100
0244	151 - 201	683,076	1.967	2.387	-0.191	0.276	99.858	99.999	99.999	100
0244	201 - 251	684,008	1.589	1.875	-0.116	0.266	99.931	100	100	100
0244	251 - 301	684,495	1.449	1.988	-0.123	0.258	99.854	100	100	100
0244	301 - 351	684,727	1.031	2.614	-0.151	0.251	99.864	99.997	99.997	100
0244	351 - 400	671,119	0.999	2.085	-0.195	0.254	99.944	100	100	100

Table 16: Multibeam crossline statistics.

4.1.3 Feature Detection, Search and Bathymetric Coverage

The minimum standard for feature detection for an Order 1a survey are cubic features > 2 metres in depths up to 40 metres and cubic features >10% of depth beyond 40 metres. This means that in 40 metres water depth 9 soundings are required in a $2m^2$ bin and in 100 metres water depth 9 soundings are required in a $10m^2$ bin. Feature detection criteria is not specified in IHO standards for Order 2 surveys.

The shelf bathymetry varies from 140 to 397 metres. Assuming Order 1a, this implies that at the minimum depth value (140 metres) the feature detection criteria is 14 metres. Figure 9 shows the feature detection statistics, i.e. the number of soundings in a 14 metre grid. The mean number of soundings per bin is 66, easily exceeding the 9 required for Order 1a feature detection.

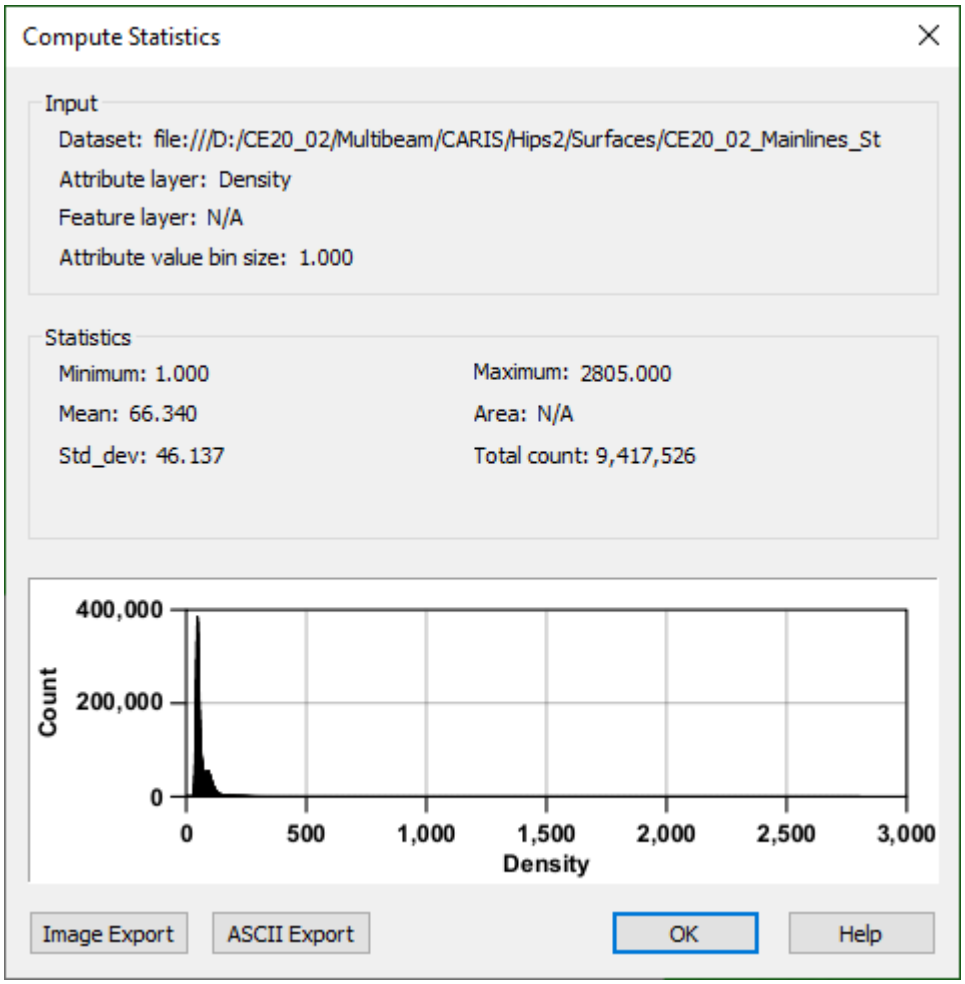


Figure 9: Feature detection statistics.

Figure 10 shows the corresponding sounding density plot for the area with green indicating where at least 9 pings per bin were achieved and red where this failed. Red colours are sporadic on this plot. This plot illustrates that the feature detection criteria for Order 1a was achieved. The data density plot along with the bathymetry image elsewhere in this report demonstrate that 100% bathymetric coverage and feature search of 100% were achieved.

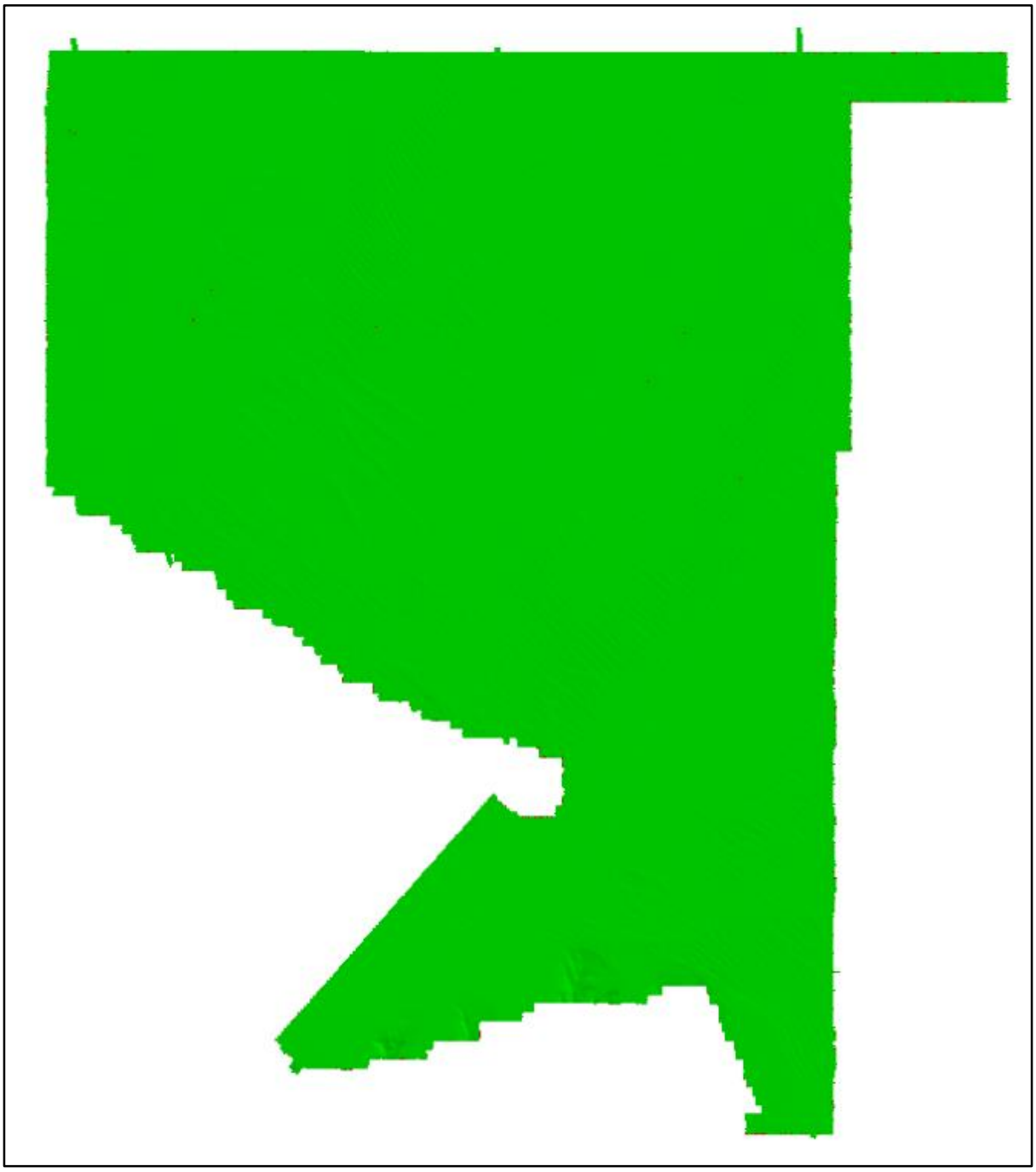


Figure 10: Sounding density QC plot.

4.1.4 Error Budget and Uncertainty Model

Manufacturer values for positioning and sounding errors were factored into the vessel error budget. Vessel offsets were established through an onshore dimension control survey (see section 3.1). In addition; uncertainty levels over positions of soundings were improved through good sound velocity control while surveying. Calibration of the MBES through a

standard patch test, combined with good online quality control, ensured that the vessel's error budget fell within IHO 1a specifications.

Table 17 below details Standard Deviation values applied in the calculation of the vessel's Total Propagated Uncertainty (TPU) model. TPU is an estimate of the uncertainty of any individual sounding, taking into account the uncertainty estimates of the component measurements (tide, sound speed, draft, range measurement, angle measurement, attitude, offsets etc). TPU is expressed as a separate value in horizontal and vertical planes. The uncertainty of each sensor was entered in the HIPS Vessel File (HVF) and the TPU calculated.

Heading Accuracy	0.065 deg
Heave	5 cm or 5 % Amplitude
Roll	0.01 deg
Pitch	0.01 deg
Pitch Stabilised	0.00 deg
Position Navigation	0.1 m
Timing Transducer	0.00 s
Timing Navigation	0.00 s
Timing Gyro	0.00 s
Timing Heave / Pitch / Roll	0.00 / 0.00 / 0.00 s
Sound Velocity Measured	0.001 m/s
Sound Velocity Surface	0.001 m/s
Offsets X / Y /Z	X=0.01 / Y=0.01 / Z=0.01
MRU Alignment	Gyro=0.1 / Pitch=0.1 / Roll=0.1
Vessel Speed	0.03
Vessel Loading	0.00
Vessel Draft	0.00 (Use of GPS tides)
Delta Draft	0.00

Table 17: Standard deviation values used in TPU calculation.

4.1.5 Sound Velocity Control

MVP's were acquired frequently. Profiles served the dual purpose of calibrating the echosounders and investigating the characteristics of the water column. Profiles were checked, extended, entered to the online systems as necessary and imported into the MBES processing software. MVP profiles are plotted in Figure 11. Sound velocity varies from up to 1506 m/s near the surface to 1494 m/s at depth. Many of the profiles show a thermocline at depths of between 35 and 60 metres.

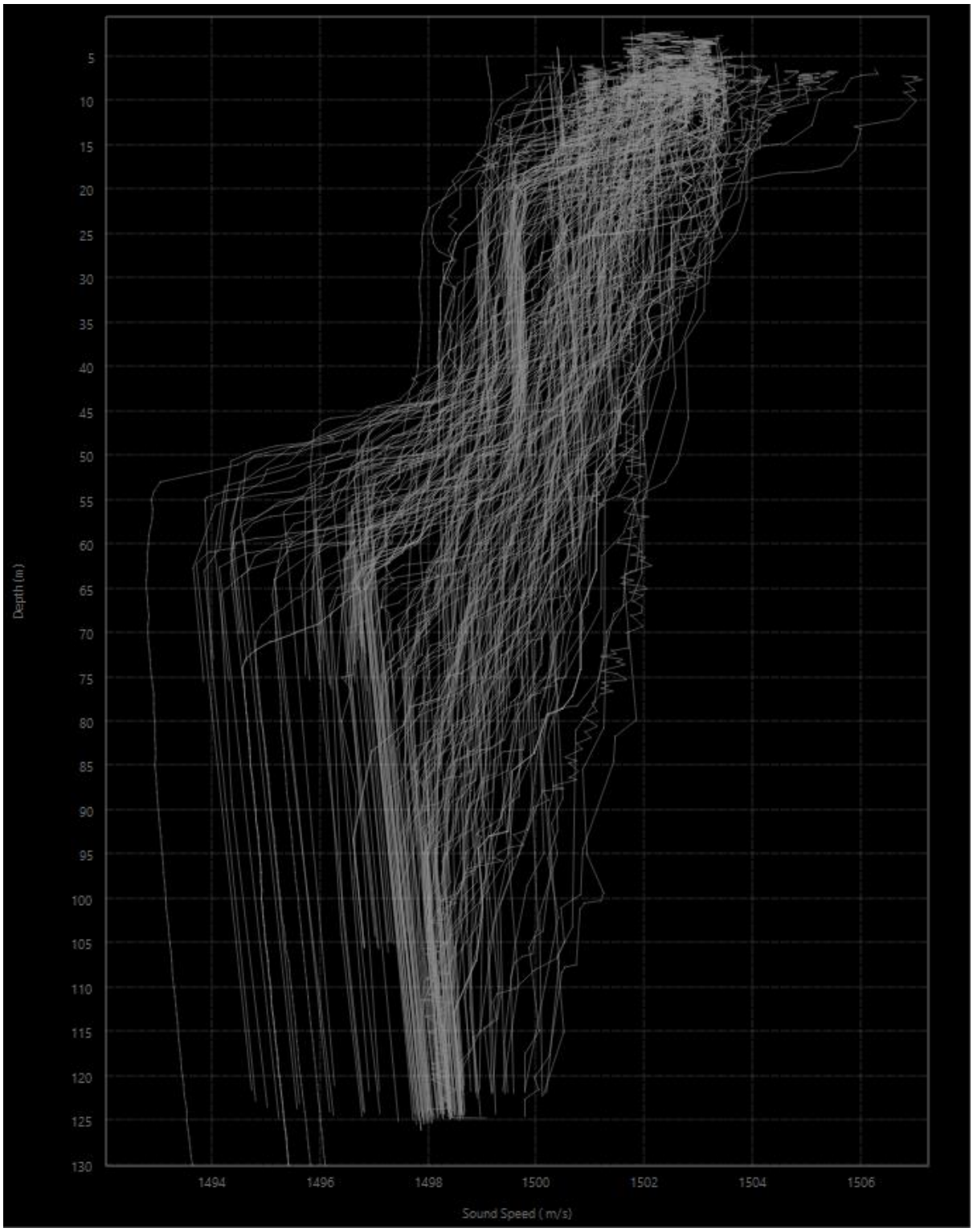


Figure 11: MVP composite casts.

4.2 Post Processing Methods

4.2.1 Navigation

Navigation data was logged in standard C-Nav format. The real time overall quality of the C-Nav positioning system is of high quality and meets IHO Order 1a standard. Vertical errors on the GPS heights are also low (+/- 20 cm) and provide a robust solution for computation of GPS tide.

Navigation data and in particular GPS heights were despiked and smoothed in Caris HIPS. GPS tide was computed using the separation model between International Terrestrial Reference Frame (ITRF) datum and VORF LAT.

4.2.2 Depth Soundings Data Processing

Soundings were edited in Caris HIPS and Qimera processing software against an existing chart background. Combinations of automated and manual processing procedures were applied by experienced data processors to remove systematic errors and obvious outliers. Uncertainty results were examined to ensure they fell within IHO specifications for Order 1a and Order 2 surveys. Processed and cleaned data were subjected to final validation by an experienced and qualified hydrographer. The following is a simplified list of steps undertaken during sounding data processing:

1. Navigation data were applied to survey data.
2. GPS tides were computed using the UKHO's VORF model. This reduced the MBES depth soundings to LAT. GPS tide results were then checked for quality and consistency.
3. TPU values were calculated.
4. SVP data were applied to correct for refraction errors caused by water column heterogeneity. A range of SV algorithms were used to determine the most suitable method of applying SV corrections, for example: nearest in distance versus nearest in time.
5. Qimera's "*TU Delft Sound Speed Inversion*" tool was used to correct refraction issues.
6. Subset Editing was performed in CARIS to clean large "noise" spikes from the data.
7. A CARIS Combined Uncertainty and Bathymetry Estimator (CUBE) base surface was then created to allow CUBE automatic filtering.

8. Final verification of sounding consistency and absence of spikes was carried out using subset editing.
9. Export of final products from Caris: Multibeam Bathymetry grids, Shaded Relief geotiffs, XYZ and track line grids.

4.2.3 Backscatter Mosaic Generation

Backscatter is a function of the hardness and roughness of the seafloor. Raw multibeam data was put through the Geocoder engine in QPS Fledermaus Geocoder Tool (FMGT) to produce backscatter mosaics of 2 m and 5 m resolutions for the shelf area and 30 m resolution for the deep area.

4.3 Survey Results and Data Interpretation

A preliminary interpretation of MBES and SBP data was used to assess bathymetry, seabed texture, seabed features, and shallow geology for this report.

4.3.1 Multibeam Images

EM2040 data were used to produce final data products. Grids and geotiff images were created in Caris Hips software of EM2040 MBES bathymetry and shaded relief data. The backscatter mosaic grid was created in QPS- FMGT software. Grids and geotiff images were imported into ArcGIS. Bathymetry and backscatter mosaic tiff images were created in ArcGIS and are presented in Figures 12 to 17 along with a shaded relief tiff image.

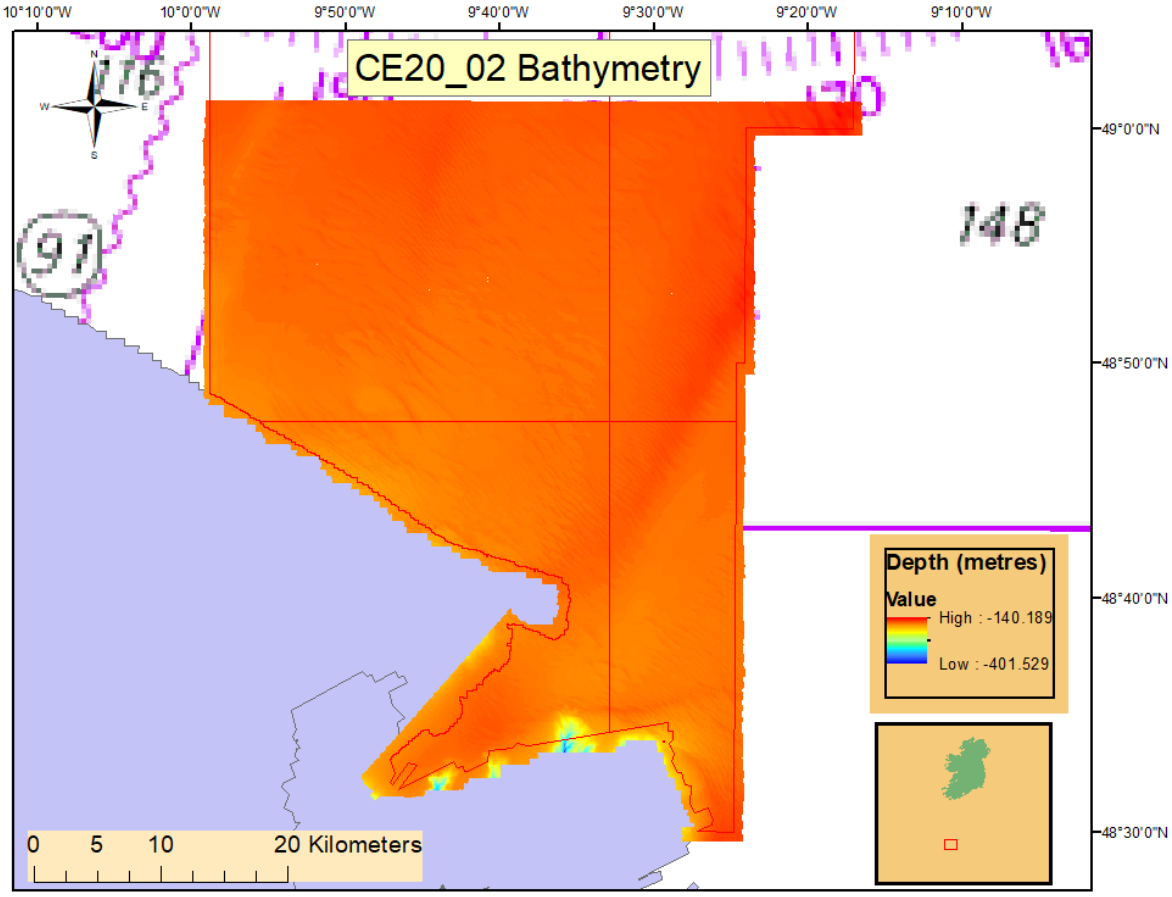


Figure 12: Multibeam bathymetry image, shelf area.

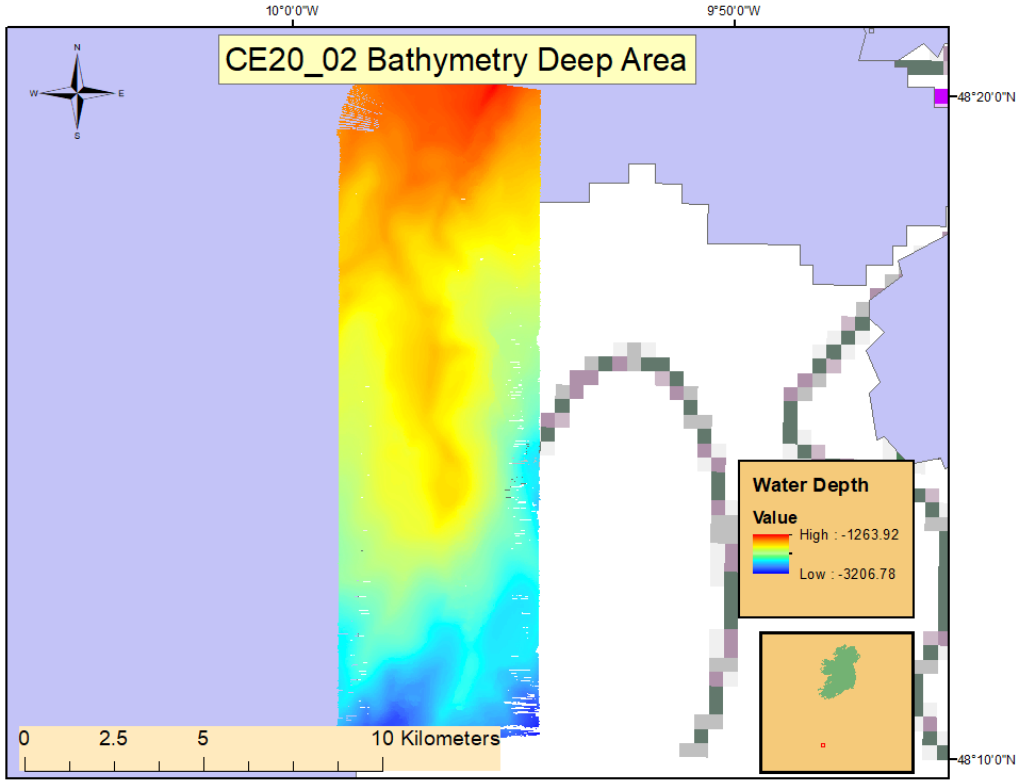


Figure 13: Multibeam bathymetry image, deep area.

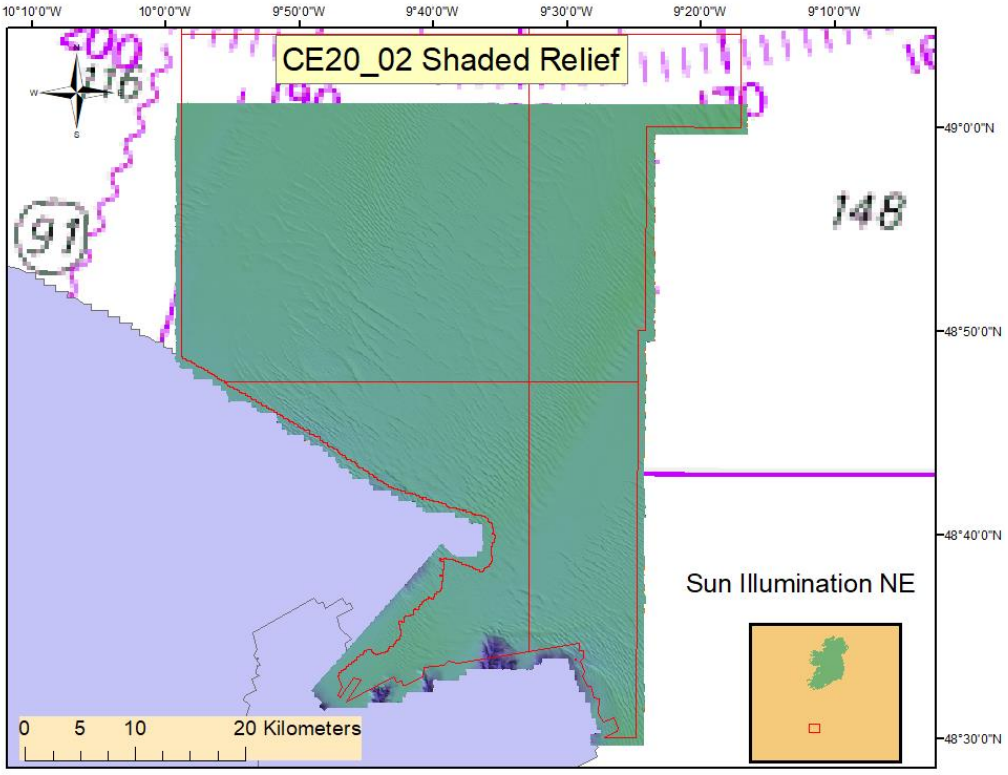


Figure 14: Multibeam shaded relief image, shelf area.

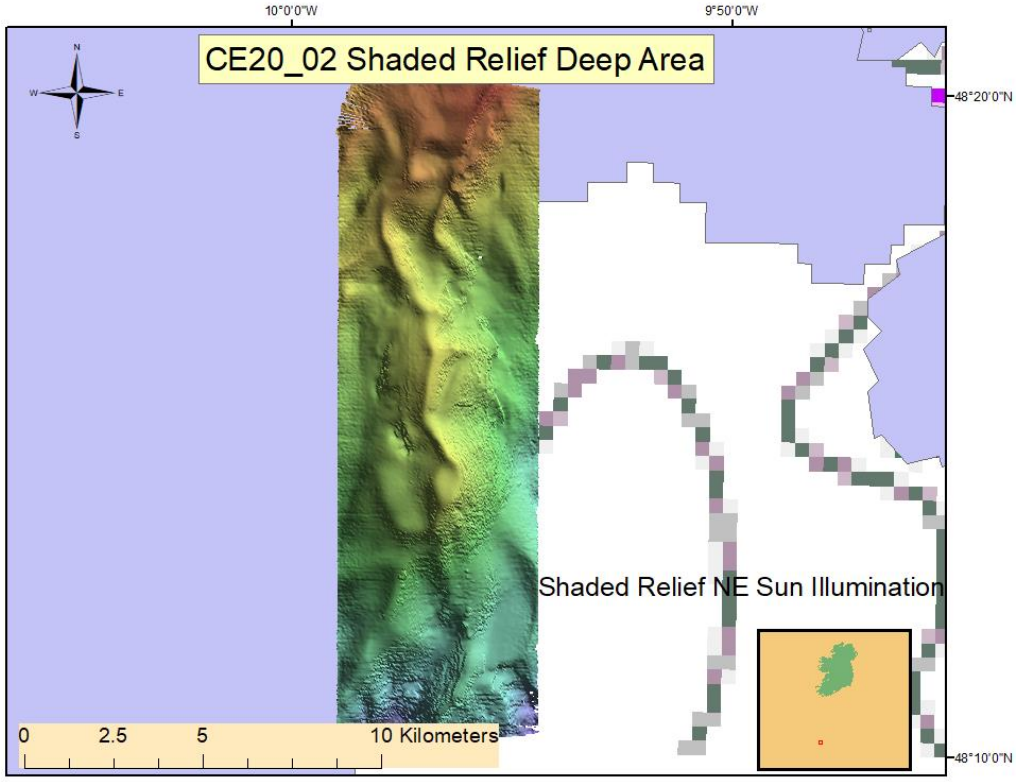


Figure 15: Multibeam shaded relief image, deep area.

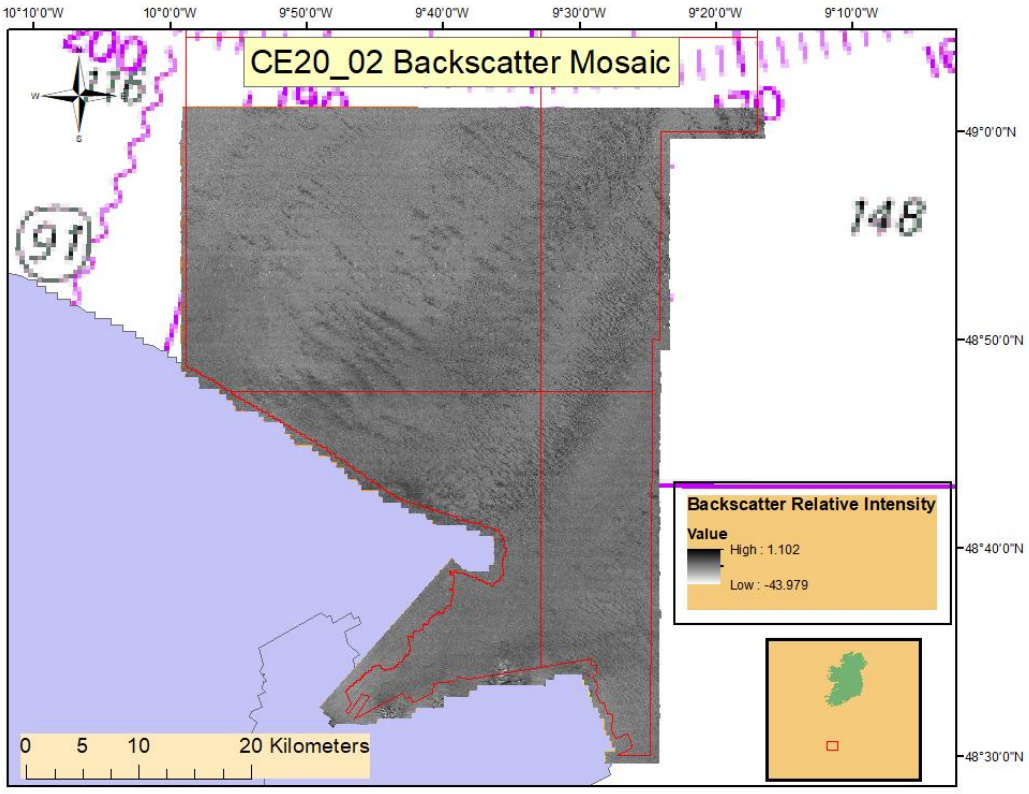


Figure 16: Multibeam backscatter mosaic image, shelf area.

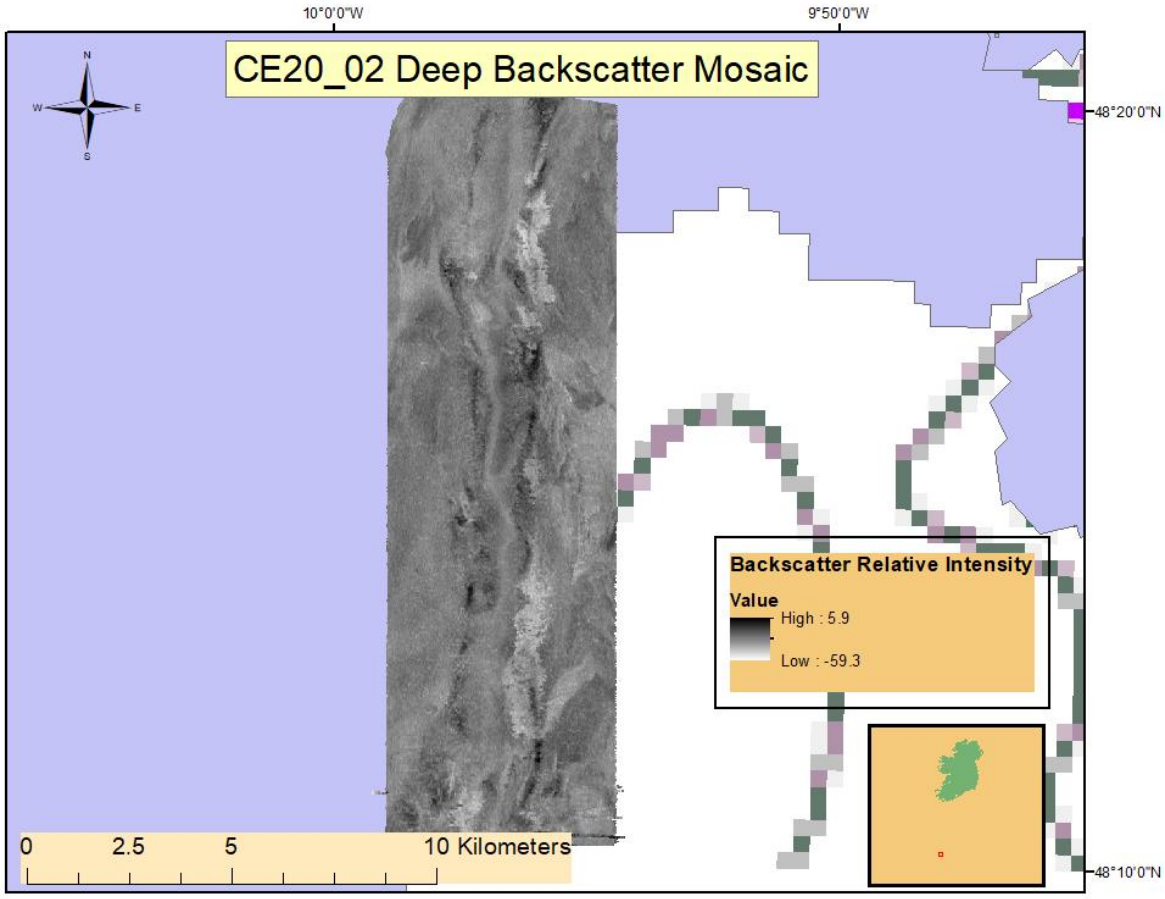


Figure 17: Multibeam backscatter mosaic image, deep area.

4.3.2 Shallow Geology Analysis

Data quality and penetration varied depending on prevailing sea state, survey direction and sub-bottom geology. Survey speed (4-10 knots) was dictated by MBES data quality and weather conditions. Good quality MBES data can be acquired at speeds that compromise SBP data integrity. SBP data was generally of good quality although a very hard substrate in places limited signal penetration. Delph Roadmap software was used to process the raw data with TVG, AGC, heave correction and stacking applied.

Figure 18 shows the track lines for profile lines, 91 and 242 selected for analysis in this report. Profiles 91 is a mainline and profile 241 a cross line, orientated W-E and N-S respectively. The track lines are overlain on MBES backscatter.

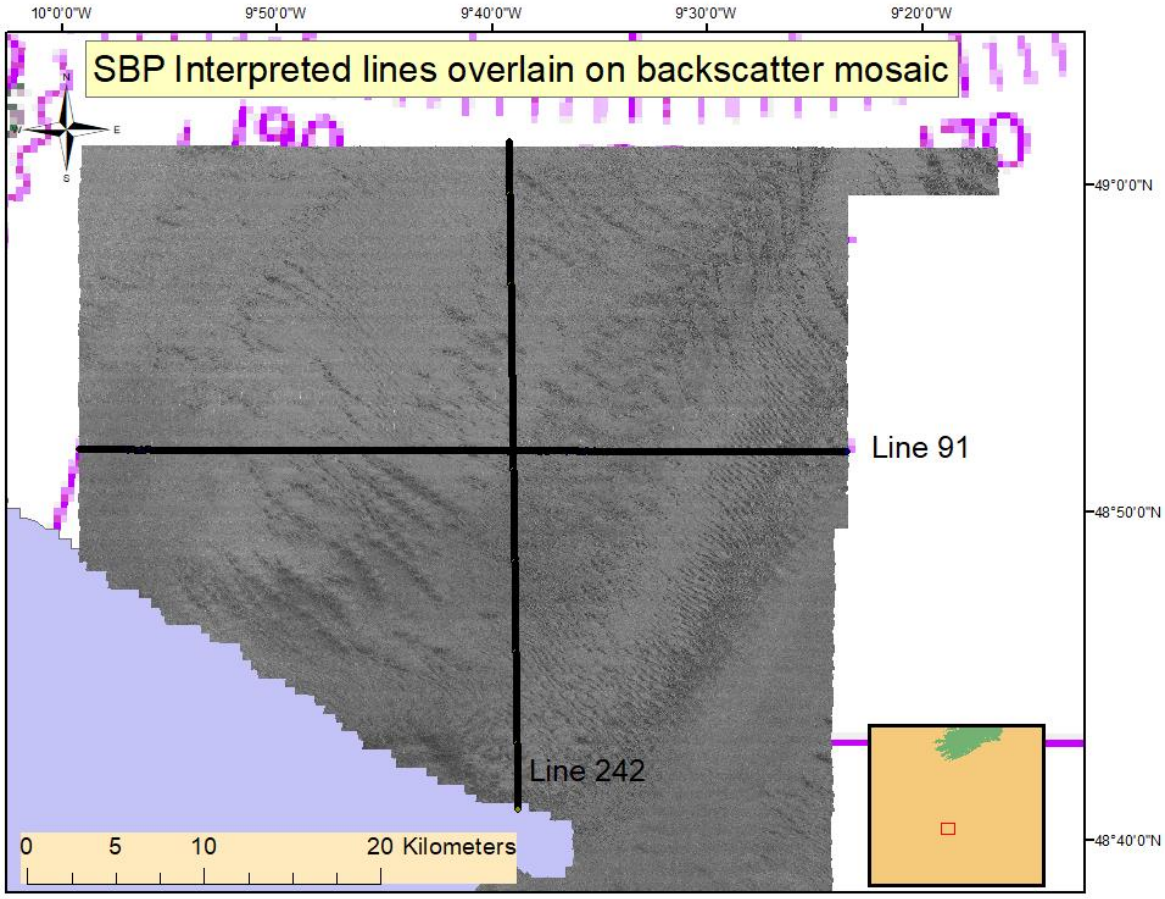


Figure 18: Multibeam backscatter overlain with tracks of selected profiles.

Profile 91

Figure 19 is an image of SBP line 91. The profile was acquired on an easterly heading and it spans the entire shelf area mapped. Vertical scale lines are at 1 km intervals and horizontal scale lines at 10 m. Total profile length is 43 km. The seabed topography is dominated by a large ridge, of c. 20 m in amplitude at the profiles eastern end.

Reflectors are not seen beneath 15 m depth. Two distinct sedimentary units are identified on the profile. Horizon 1, an unconformity, is evident across most of the profile and marks the boundary between Unit 2 beneath and Unit 1 above. Horizon 1 is at a depth of less than 15 m beneath seabed. It cannot be traced beneath the ridge at the eastern end of the profile.

Unit 2 is acoustically featureless. The base of Unit 2 is not seen. Unit 1 unconformably overlies Unit 2. Sporadic discontinuous internal reflectors are evident in Unit 1. The top of Unit 1 is the seabed and is characterised by numerous sediment waves of varying scale with the sediment waves also found on the ridge surface. Largest sediment waves are 7 m in amplitude with wavelengths of up to 1 km. The sediment waves have a variety of symmetries.

Profile 242

Profile line 242 in Figure 20 is a cross line located in the centre of the shelf area and orientated north-south. The profile is 37 km in length. Two sedimentary units are identified. Unit 2 is the oldest unit. Its base is not seen. Unit 2 is present over the profile extent. The top of Unit 2 is denoted by the unconformity, Horizon 1. Horizon 1 is an undulating surface with several incised channels. Unit 1 unconformably overlies Unit 2. Unit 1 varies in thickness up to a maximum of approximately 12 metres. Unit 1 contains numerous laterally discontinuous internal reflectors. Sediment waves are evident on the seabed in multiple locations. The sediment waves have amplitudes of up to 4 metres with largest wavelengths of up to 1 km.

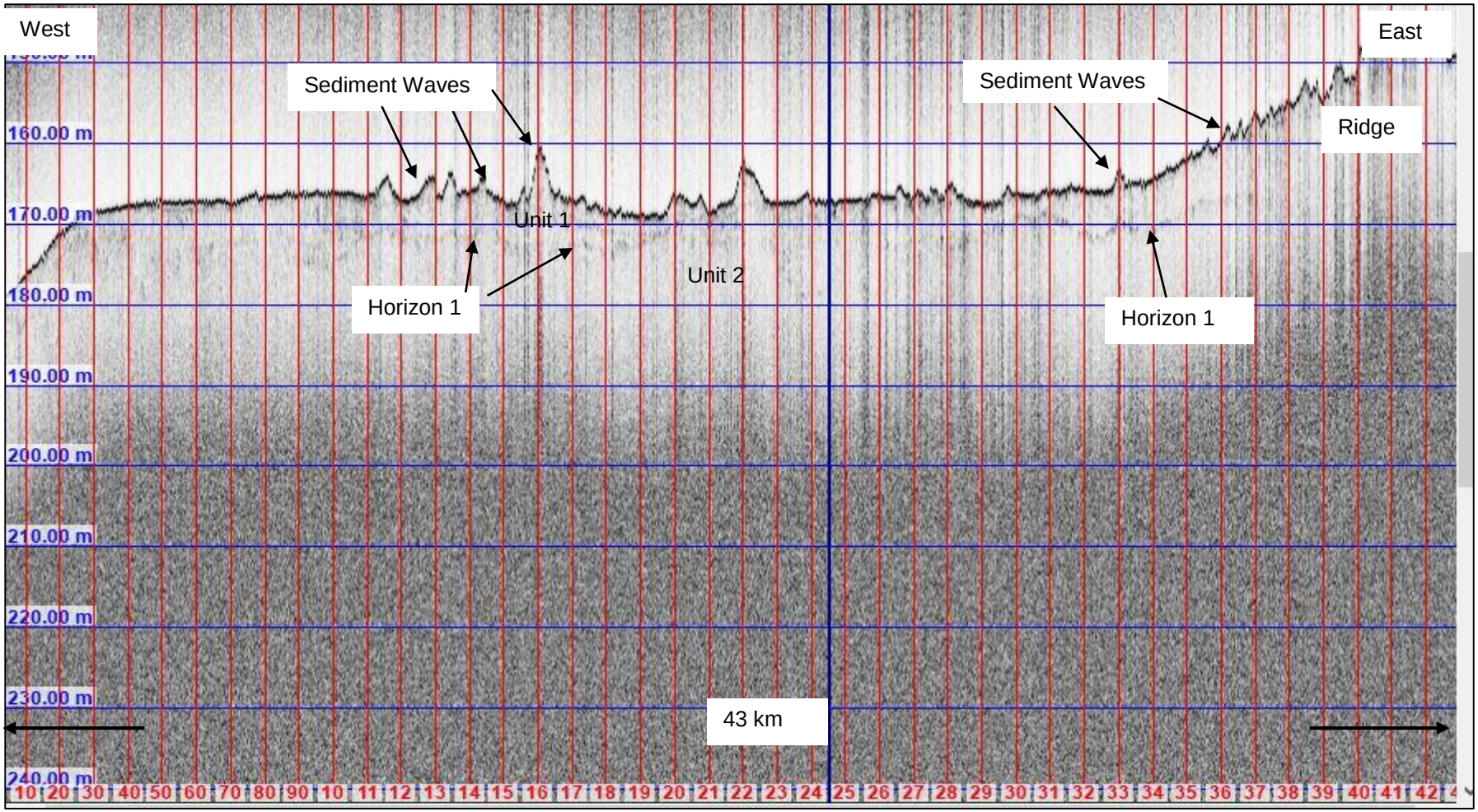


Figure 19: Sub bottom profiler data, main line 91.

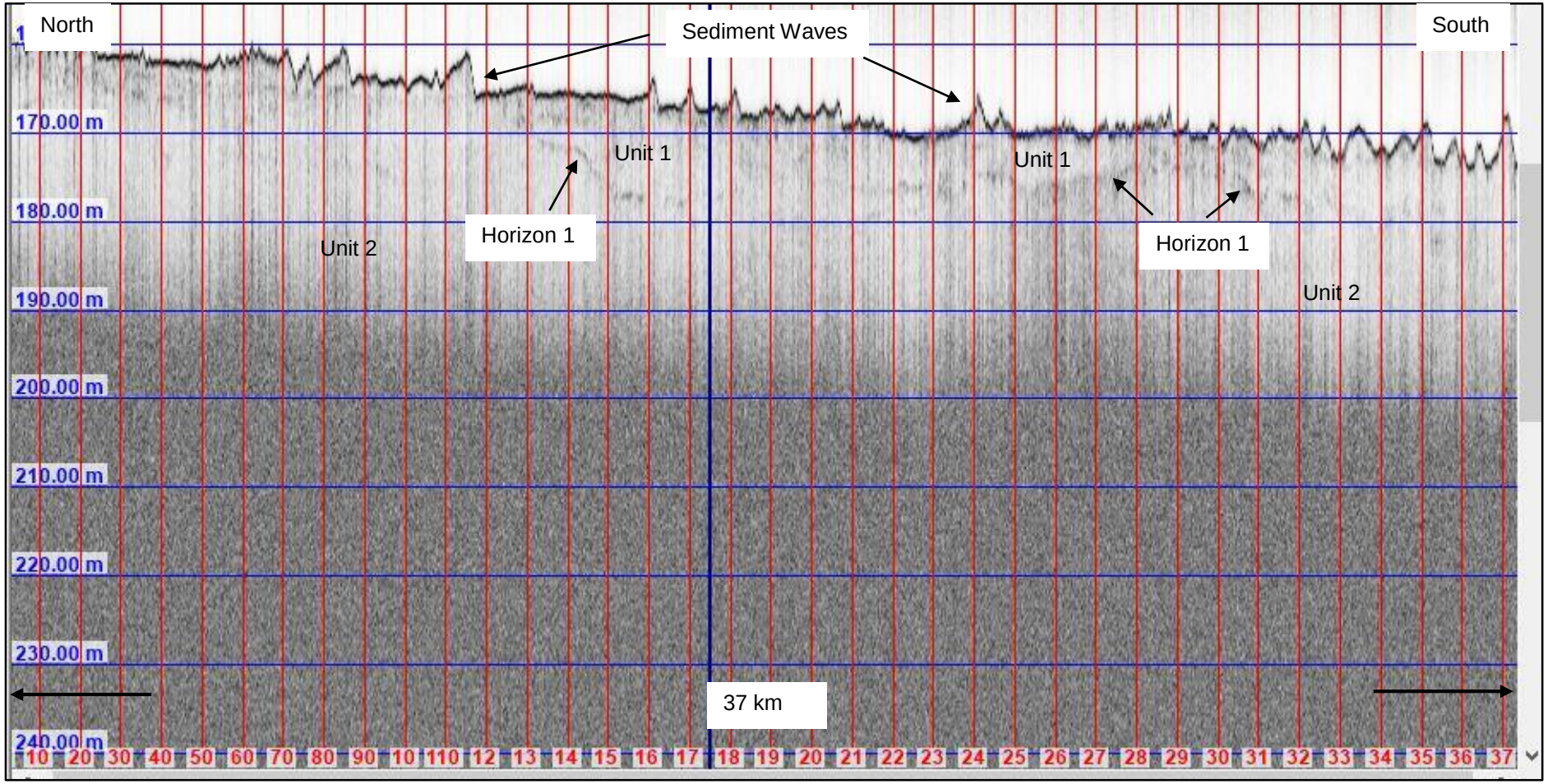


Figure 20: Sub bottom profiler data, cross line 242.

4.3.3 Bathymetry

An overview of the shelf bathymetry image, gridded at 5 m is presented in Figure 21. Water depth varies from 140 to 402 metres. Shallowest depths are in the northeast and greatest depths in the south. Sediment waves located in the central part of the area are typically less than 5 metres in amplitude. Seabed gradients are very low over most of the area with the exception of localised higher gradients around sediment waves and at canyon heads in the southern margin of the mapped area. Seabed gradients of greater than 15° are found in these canyons.

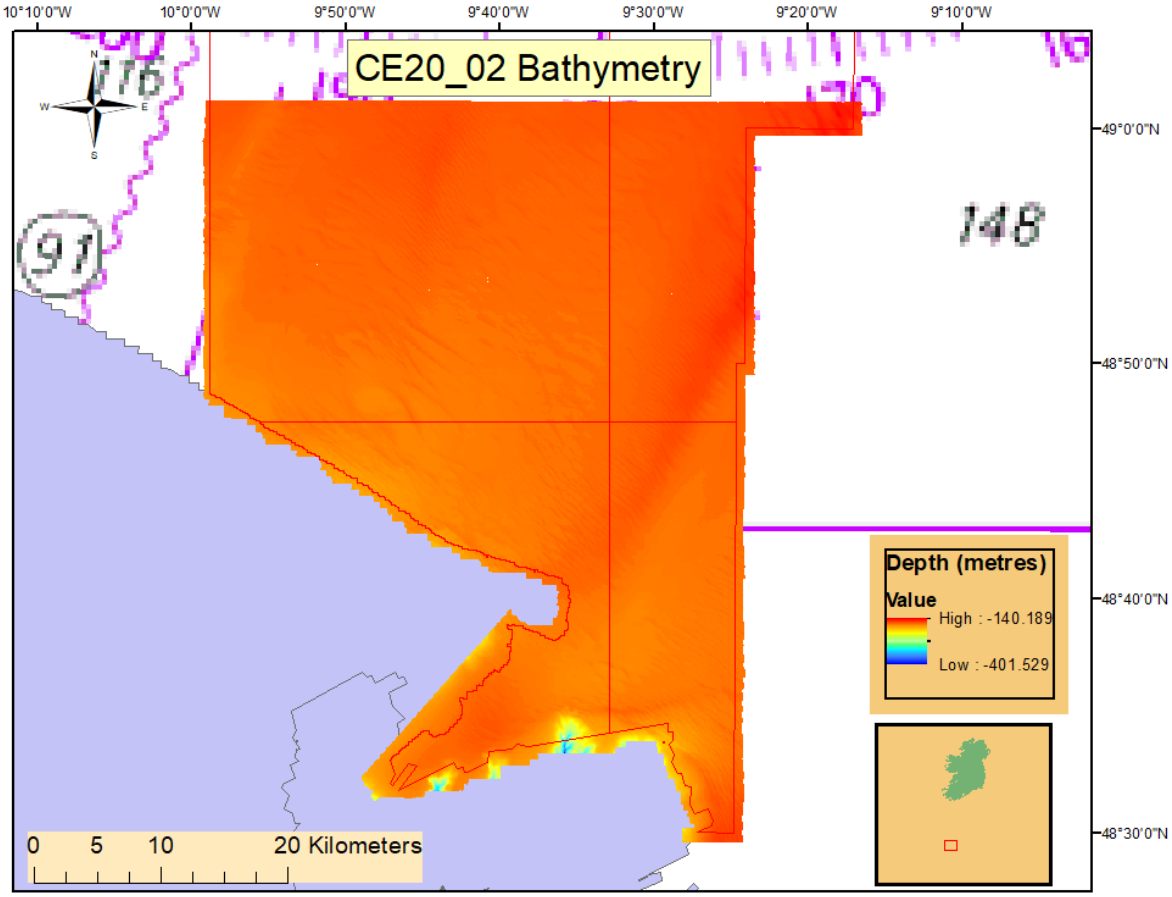


Figure 21: Multibeam bathymetry overview, shelf area.

Figure 22 is the bathymetry image of the deep water area, gridded at 20 metres. Water depth varies from 1264 metres in the north to 3203 metres in the south. Low angle seabed gradients are typical. The dominant bathymetric feature is a large sinusoidal ridge which spans the northern 2/3 of the area and runs downs the centre of the mapped area.

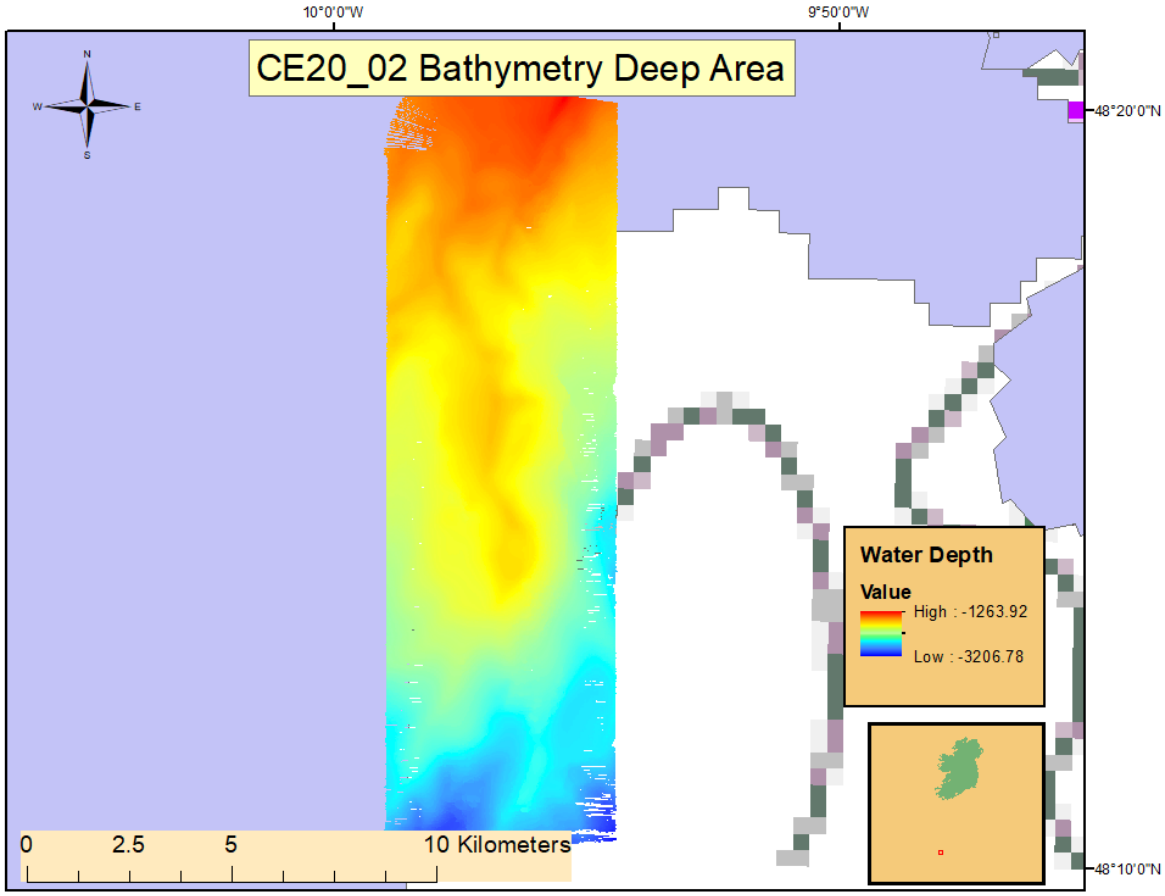


Figure 22: Multibeam bathymetry image, deep area.

4.3.4 Seabed Texture

Multibeam backscatter is the amount of acoustic energy being received by the sonar after a complex interaction with the seafloor. Analysing the amplitude of the returning sound waves enables us to extract information about substrate structure and hardness, allowing for identification of substrate types. Seabed reflectivity properties depend on the hardness and roughness of the seafloor surface. In simple terms a strong return signal indicates a hard and/or rough surface and a weak return signal indicates a soft, smooth surface.

EM2040 multibeam data was used to produce backscatter images in this report. EM302 backscatter data was also acquired. Figure 23 is the backscatter mosaic for a subset of the shelf area. It illustrates an intricate pattern of backscatter types and relationships which

reflect the diverse nature of the substrate. The convention used is that dark coloured areas represent relatively higher intensity (stronger) returns than light coloured areas.

Homogeneous low and medium backscatter intensity is the dominant type of substrate in the SE of the image. Further northwest the substrate is dominated by discrete linear ribbons of high intensity backscatter interspersed with a background of low and medium strength backscatter substrate. The ribbons are orientated along NE to SW axes and vary from hundreds of metres in length to several kilometres in length with widths of less than 100 metres. The backscatter mosaic in the NW part of the image displays an intricate pattern of backscatter types, annotated as mixed backscatter. These have various orientations.

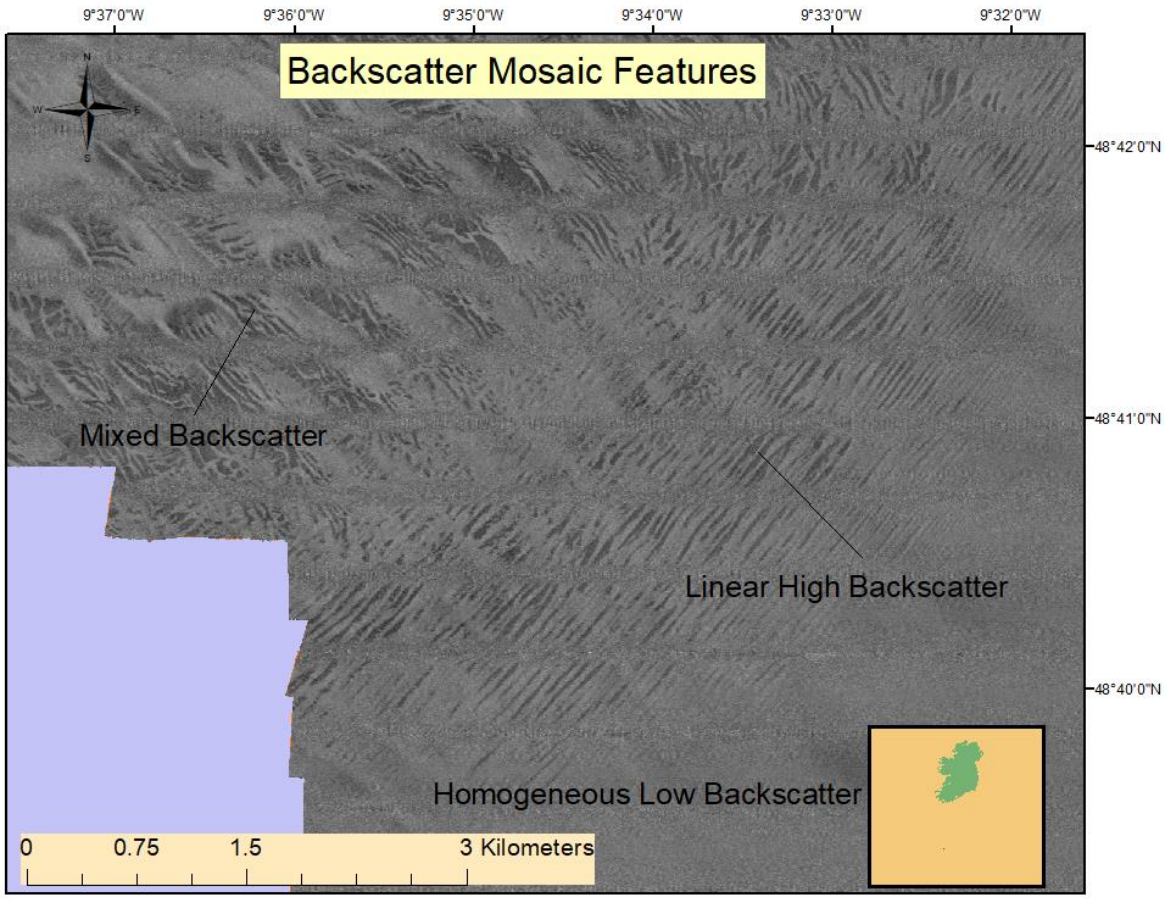


Figure 23: Backscatter mosaic features, shelf area.

Figure 24 shows the backscatter mosaic for the entire area. Relatively low backscatter intensity types are dominant. Very low backscatter intensity is evident in the south within the

canyon heads. These are situated at the shelf edge in areas where the bathymetry is at least 100 metres deeper than the majority of the area mapped. High backscatter areas form linear features on the mosaic image and are associated with troughs between sediment waves.

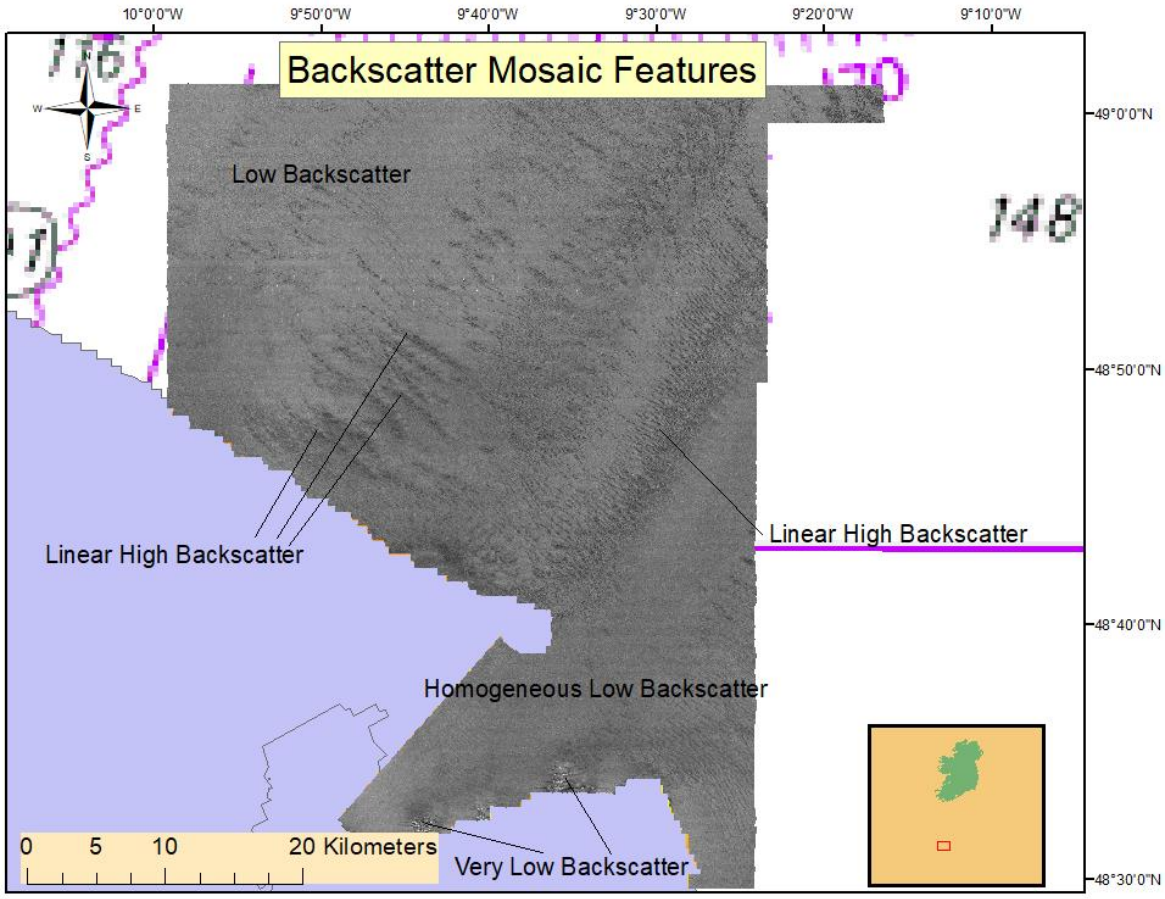


Figure 24: Backscatter mosaic features shelf area overview.

4.3.5 Seabed Features

Description of seabed features is based on analysis of bathymetric, shaded relief and backscatter data. It is possible to make valid inferences on seabed character and composition by correlating these datasets. Shaded relief data is used to illustrate the features discussed in this section. Shaded relief imagery is produced in Caris by shining an imaginary sun at 35º angle over the depth colour coded multibeam bathymetry dataset.

Figure 25 is a shaded relief image gridded at 5 metres with sun illumination from the NE. It illustrates a sediment wave dominated seabed. Sediment wave crests are orientated along

NW – SE axes. Typical amplitudes are 3 or 4 metres with wavelengths of 300 to 400 metres and some of these sediment waves extend for more than 10 km.

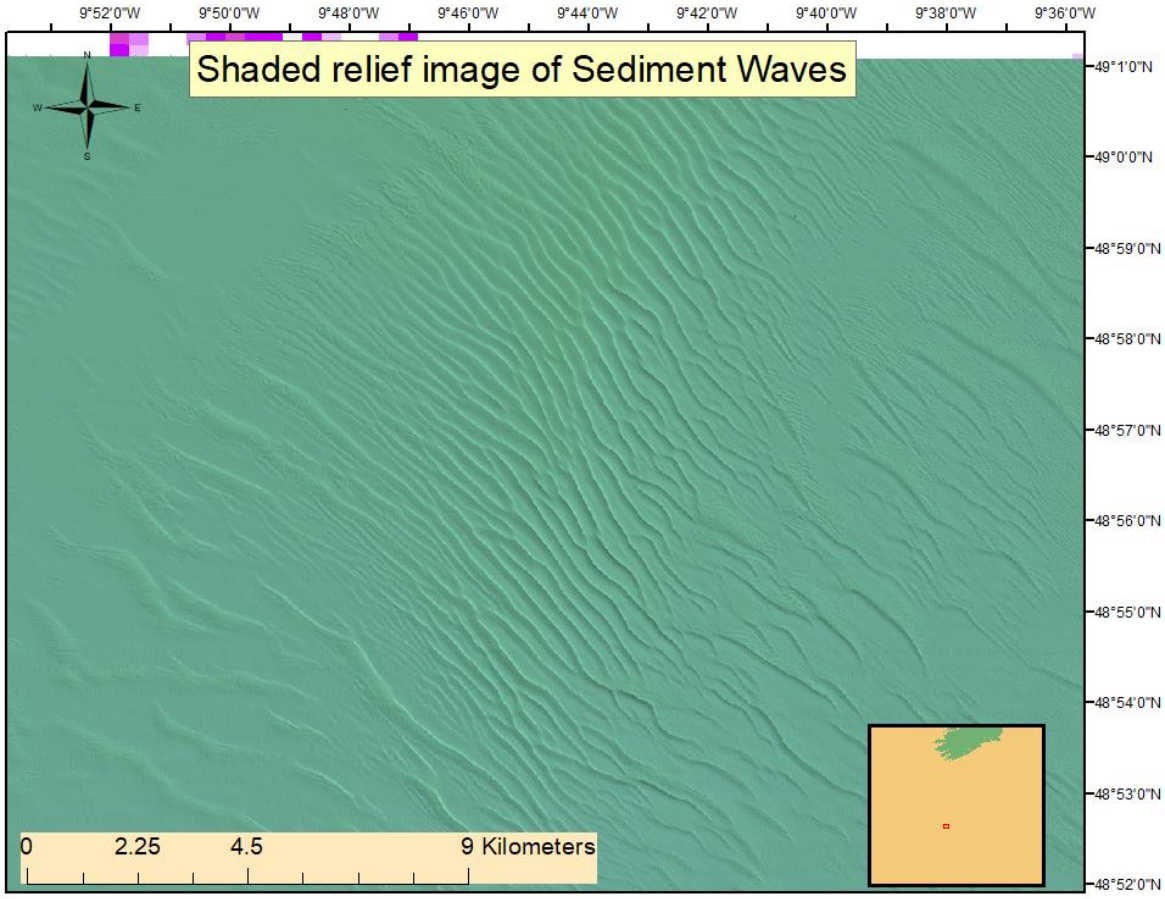


Figure 25: Multibeam shaded relief illustrating sediment waves.

Figure 26 is a shaded relief image with NE sun Illumination of a shelf edge canyon head. The relief between the shelf and the canyon channel is c. 130 metres. Sediment waves are evident with the channel floors. Scarp, terracing, meandering channels and canyon walls are features evident on the image. A numbers of these canyon heads are found at the shelf edge at the southern extent of the survey.

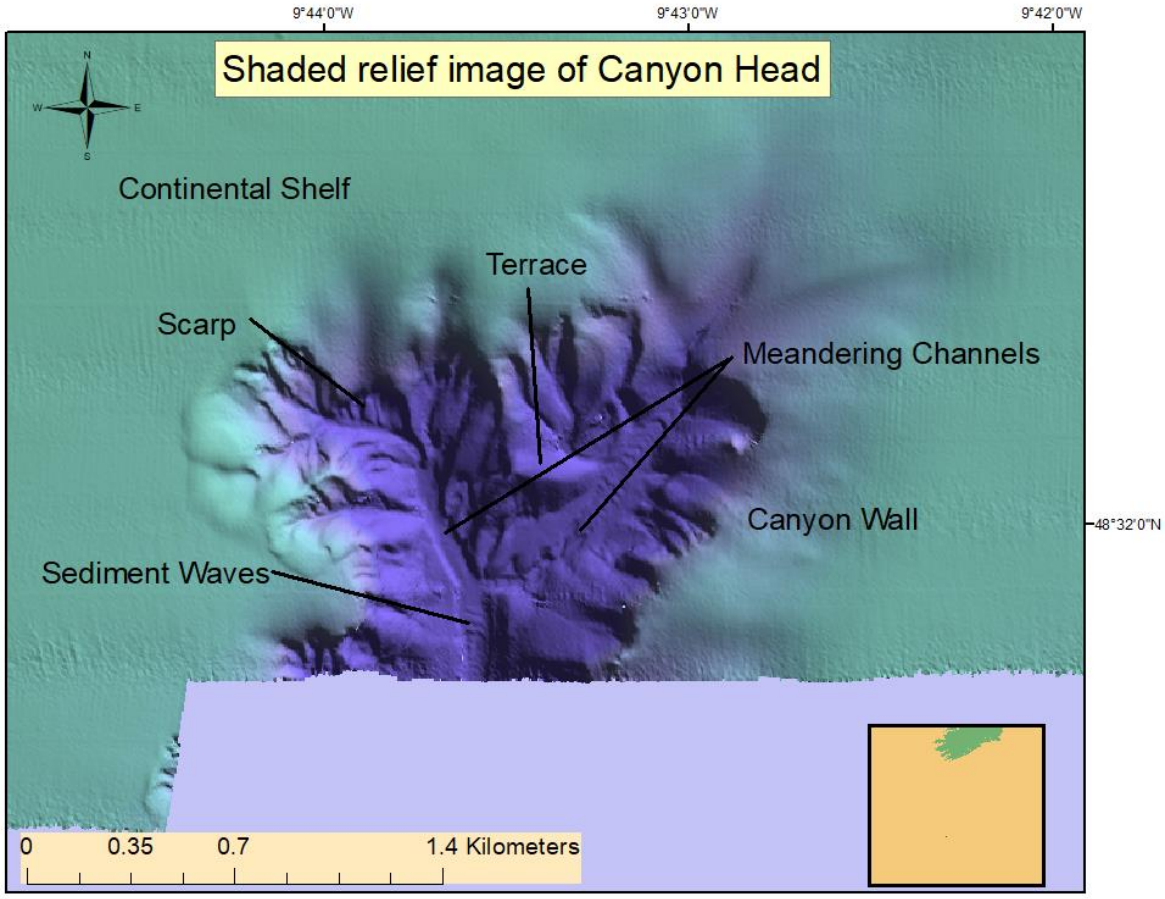


Figure 26: Multibeam shaded relief illustrating canyon head.

4.4 Groundtruthing

Groundtruthing was not undertaken during this survey. Future surveys will groundtruth this area.

4.5 Wrecks

Nine wreck sites were identified from multibeam and magnetometer data and detailed wreck surveys were completed. Table 18 lists the wreck metadata.

Number	Length / m	Name	Latitude	Longitude
1	91.8	Unknown	49°00.209 N	-9º 28.955 W
2	112.0	Unknown	48°58.792 N	-9º 25.436 W
3	113.5	Unknown	48°50.937 N	-9º 46.160 W
4	75.0	Unknown	48°54.066 N	-9º 25.069 W
5	119.0	Unknown	49°50.699 N	-9º 23.500 W
6	88.0	Unknown	48°47.213 N	-9º 36.730 W

7	126.0	Unknown	48°42.712 N	-9º 32.344 W
8	63.9	Unknown	48°34.618 N	-9º 33.147 W
9	76.7	Unknown	48°31.884 N	-9º 26.792 W

Table 18: Wreck metadata.

Figure 27 shows the location of the mapped wrecks overlain on the multibeam shaded relief data. Mapped wrecks have a red symbol and are numbered corresponding to the table above. Mapped wrecks are unidentified at the time of writing.

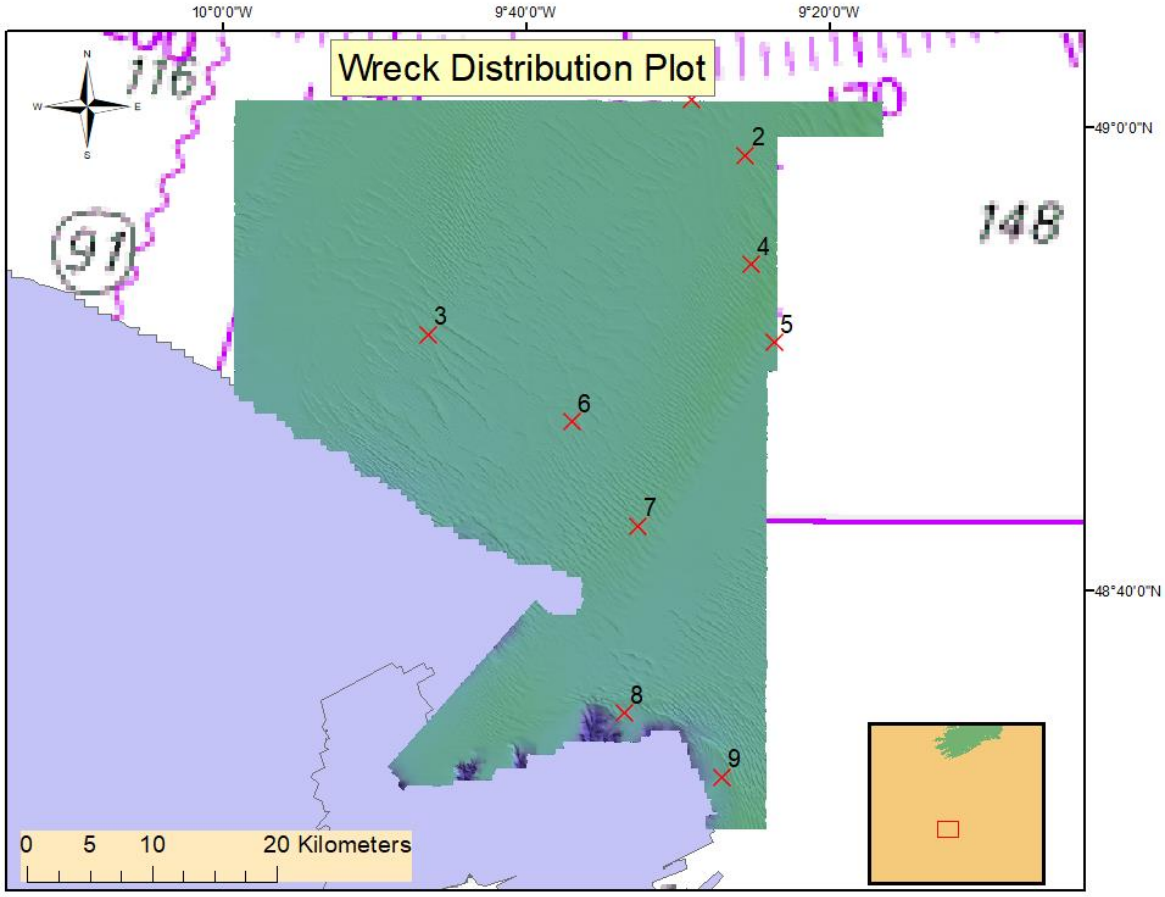
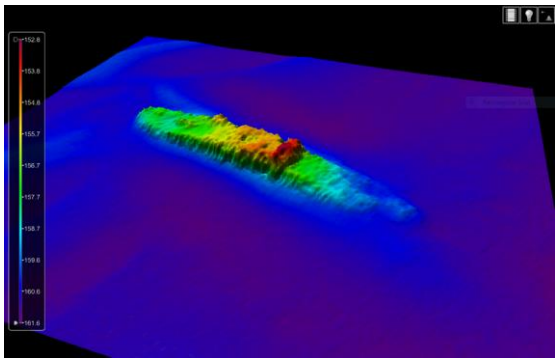
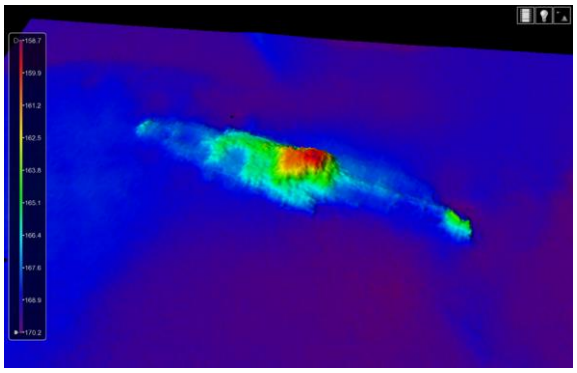
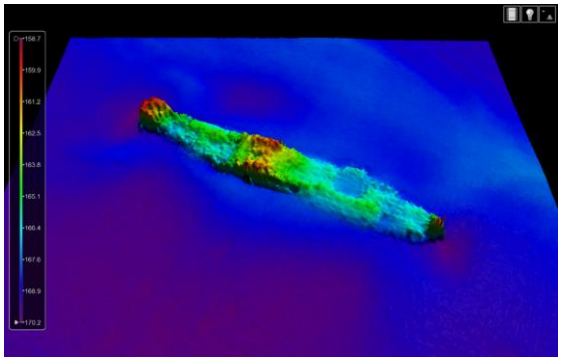
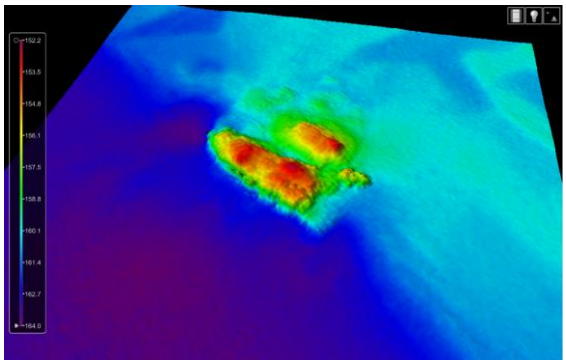
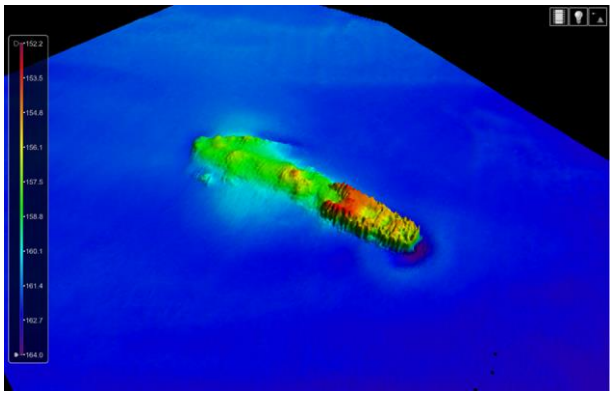
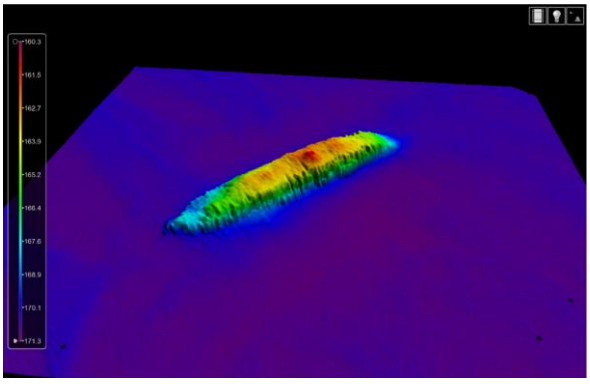


Figure 27: Mapped wrecks overlain on shaded relief data.

Table 19 contains multibeam data images of the nine mapped wrecks.

Wreck 1	Wreck 2
	
Wreck 3	Wreck 4
	
Wreck 5	Wreck 6
	
Wreck 7	Wreck 8

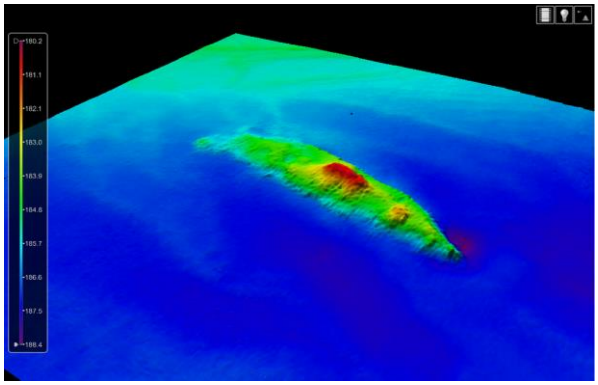
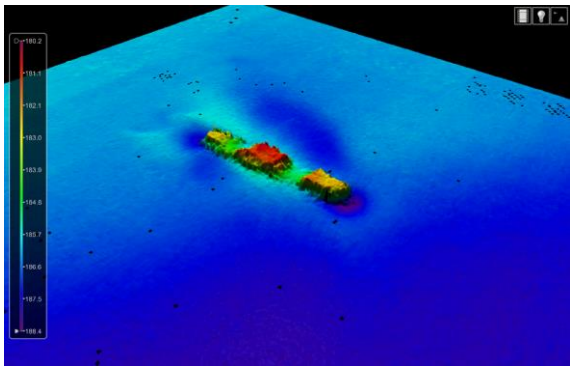
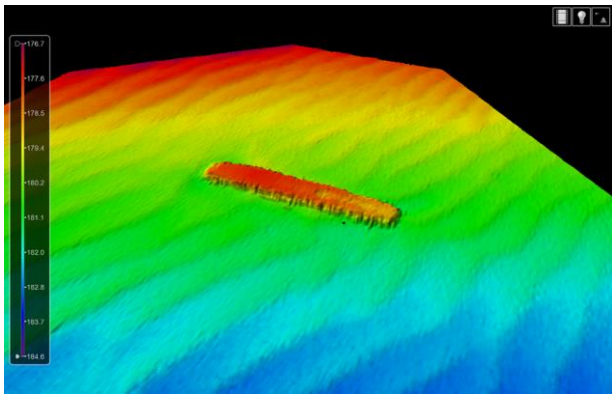
	
Wreck 9	
	

Table 19: Multibeam data wreck images.